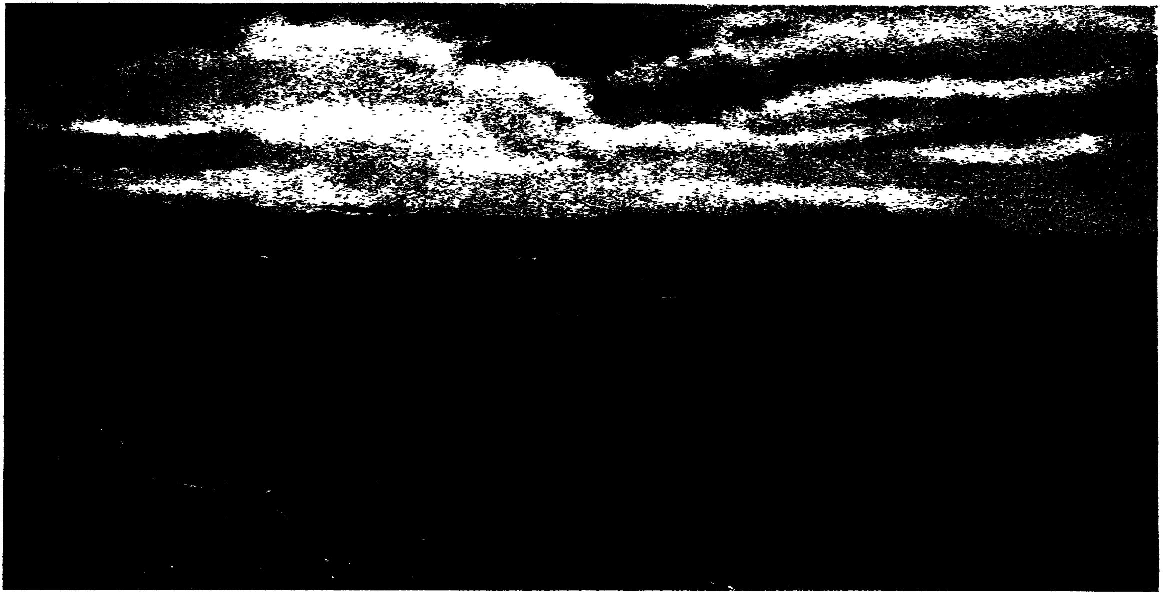

Plate 1. Across Shenandoah Valley to Shenandoah National Park from near Luray. The broad plain is part of the Valley-floor peneplain which truncates highly folded sedimentary rocks. (Photograph by W. K. Rhodes.)

CAVERNS
OF
VIRGINIA

WILLIAM M. McGILL

UNIVERSITY, VIRGINIA

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CAVERNS OF VIRGINIA

BY

WILLIAM M. McGILL
Assistant State Geologist

Foreword

"Caverns Measureless to Man"

IT IS NOT difficult to understand the irresistible appeal which caverns make to the imagination. Even the most commonplace cave has a certain indefinable mystery and fascination. The very word is associated with romantic and thrilling things. In caverns explorers have been lost, pirates have held rendezvous, brigands have plotted, refugees have hidden, treasure has been buried and wild beasts have had their lairs. There is scarcely a boy who has not at some time tried to dig a cave, and we all in our youth followed in imagination with breathless excitement the wanderings of Tom Sawyer and Becky through the labyrinth of Indian Joe's cave.

But human association pales in significance beside the miracles wrought by nature in her caverns. With endless time at her disposal but with no tool other than water—water dissolving the soluble rock, or depositing liquid stone drop by drop from the ceilings of chambers the waters have carved—nature excavates and furnishes and decorates rooms and halls and corridors of a splendor that baffles description.

These mysterious underground streams which have flowed where you now walk, and are now flowing elsewhere in the solid earth beneath you, how they challenge the imagination! Sometimes you gaze down a deep and fearful chasm, and there a hundred feet below is one of those

lost rivers, no man knowing whence it came or whither it goes. You are inevitably reminded of the passage in Genesis which speaks of the waters beneath the earth. These hidden waters have been the architects and the excavators of the caverns, some of which extend for miles, with unexplored corridors and passages leading to other sights not yet seen by human eye,

"Where Alph the sacred river ran
Through caverns measureless to man
Down to a sunless sea."

No wonder the owners turn to Arabian Nights for names to describe their marvels. Only in a supernatural world can be found descriptions that do them justice. There is nothing in ordinary aboveground life with which to compare them. Though hidden deeply in the earth, they are in their more tremendous aspects unearthly.

The feeling with which we enter a cave is one of mingled mystery and awe. There is just enough of the unknown in any large cavern, particularly if parts remain unexplored, to give the tingle and thrill of an adventure. If it is a first experience you cannot even imagine the wonders you are going to see, so versatile and original is old Mother Nature. When you read the geologist's description of how it was done, you are amazed that processes so simple and so unexciting should create such infinite variety of stone sculpture, such pinnacles and minarets, towers and castles, shields and draperies, cascades and baptismal fonts, sturdy pillars like those in some cathedral crypt and delicate lacelike tracery. These apparently endless forms and shapes have been formed by water

charged with limestone in solution working in the dark with ageless patience.

Along comes man and says "Let there be light" and lo, there is another miracle. The hidden mysteries become visible but none the less mysterious. And light adds a further charm. It is reflected from a thousand dazzling crystals, from the dripping stone icicles and in the basined pools. Nature did not include light in her scheme. She was content to create her buried fairylands though no eye ever beheld them. But man made them visible and rendered them more accessible and enhanced them. Nature pays no attention to all this but goes on with her work, enlarging her caverns or destroying them, decorating and redecorating them, as she has been doing for a million years. And a million years from now there will be new wonders for whatever eyes there are to behold.

For some reason, which seems somewhat strange, even after the geologist has given the explanation why it should be so, the western portion of Virginia is honeycombed with caverns of an unusual and striking character. Those which have been arranged for inspection are only a part of the total number known, and there are doubtless many others not yet discovered. Nor have all those now known been completely explored. The visitor passes openings, corridors and chasms leading no one knows where, which adds to the mystery and awe of the expedition. One shivers at the thoughts suggested by the words "bottomless pit," "lost river," "endless caverns."

Although the underground wonders of Virginia have never been completely explored, there is enough to satisfy the most enthusiastic subterranean visitor. And none can visit them, no matter how sluggish his

imagination, without asking "How?" It is to answer that question that this book has been prepared by the Virginia Geological Survey. Here is the simple but scientific explanation of the caverns of Virginia which constitute a wonderland more stupendous and thrilling than that which Alice found underground.

Some one has said that God left Saturn unfinished so we could see how worlds were made. In somewhat the same spirit these caverns enable us to penetrate the laboratory of nature, her workshop and her studio, and see what goes on beneath the crust of the seemingly solid earth, where she moves in mysterious ways her wonders to perform. No words can do justice to the caverns of Virginia. Even the photographs with which this book is so plentifully supplied and which so admirably supplement the text, lack the colors with which nature has painted the originals. Only a visit to at least a few of the caverns can give one any idea of their rich and varied interest. Once you have seen them, this book will have meaning. It will come alive. It is the scientist's answer to that eternal question, "How?", the geologist's explanation of one of the great mysteries of this wonderful earth of ours.

The State Commission on Conservation and Development of Virginia is expressly charged by law with the duty of studying and developing the State's natural resources. In the performance of this duty the Commission from the outset has found itself embarrassed and ofttimes at a complete loss because of the lack of sufficiently comprehensive study of the resources of Virginia, of which her natural wonders may be considered as among her most valuable.

It is with peculiar pleasure and satisfaction, therefore, that we

have exercised the privilege of examining the proofs of this work on the Caverns of Virginia, which has been written by William M. McGill, Assistant State Geologist, under the general supervision of Dr. Arthur Bevan, State Geologist of Virginia.

WILLIAM E. CARSON

Chairman of the State Commission on Conservation and Development

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CAVERNS OF VIRGINIA

By WILLIAM M. McGILL

Introduction

THE Appalachian Valley in Virginia is not only rich in tradition and historical associations but it is likewise a region of unsurpassed natural charm and scenic beauty. An ever-changing panorama of beckoning forest-clad mountains, rolling valleys and beautiful streams is offered the traveler along the Valley Highway (Route 11). Famous mineral springs and health resorts and parts of four great national forests are embraced within the Valley. Classic exposures of geologic formations and structures and outstanding natural wonders abound in the region.

Prominent among the natural wonders are the many interesting caverns and related features which occur in the beautiful Valley of Virginia and in some of the picturesque mountain ridges to the west. The caverns of Shenandoah Valley, just west of the Shenandoah National Park area, are probably the best known (Pl. 1). Some of them have a world-wide reputation for their characteristic features and for the beauty and variety of the fantastic formations which they contain. Others, less widely known, are interesting to the sightseer and to the student of geology.

Caverns are more numerous in the Appalachian Valley in Virginia than the casual visitor would imagine. In addition to having considerable popular appeal, the caverns are of scientific interest as examples of the unobtrusive but highly picturesque geologic work of underground

water. The abundant sinks, caves, lost rivers, underground streams and springs throughout the Valley testify to the important rôle of underground drainage in the development of caverns. The scarcity of surface streams in certain areas and the sudden disappearance of others underground indicate the presence of numerous subterranean drainage channels in the limestones beneath the Valley floor.

The writer describes in non-technical language the developed caverns in Virginia, points out the characteristic features of each, and tells something of their geologic origin. Not alone because of their inspiring natural beauty but also because of their educational value the caverns should appeal to all who admire the marvels of nature. To the student of geology, in particular, they offer interesting places to study some of the events in the amazing geologic history of the State.

The origin of the caverns is so intimately related to the geologic history of the Appalachian Valley that a brief outline of that history is given in Chapter II. This study of the caverns was begun in the spring of 1929 in connection with a systematic field survey of the outstanding natural wonders of the State.

Technical terms are defined in the glossary. References cited by superior numbers in the text are listed and a bibliography is given.

Most of the commercial caverns are in the northern part of Shenandoah Valley, seven of them being approximately between Waynesboro and Strasburg. The other two are in southwestern Virginia, in Roanoke and Giles counties. Numerous known undeveloped caves are found in the limestone belts west of the Blue Ridge.

CHAPTER I

Human History in the Caverns

PRIMITIVE man lived largely in caves and under projecting rock ledges or overhanging cliffs. Fossil remnants of ancient man and fragments of his crude tools and implements have been found in caves in many parts of the world. The earliest discoveries were made in western Europe, particularly in France and Spain, where systematic explorations of cavern areas were first undertaken. Later investigations revealed relics of ancient man and traces of his abode in caverns in Europe, Asia, Africa and North and South America. The caverns of the Americas, however, have not been as fully or systematically explored as have those of the Old World.

According to Hovey,[1] "the mummies, sandals, utensils and ornaments found in the Kentucky caves bear a general resemblance to the relics found in the Spanish ones." Primitive human skulls, entombed skeletons, tomb sites, pottery, stone and flint implements and accumulations of animal and bird bones have been reported from Tennessee caves.[2] Probably the richest finds in the United States are those of the ancient Pueblo ruins in Arizona, Colorado, New Mexico and Utah.

During explorations in Luray Caverns in 1878, shortly after their discovery, portions of a human skeleton were found embedded in dripstone in a room since known as Skeleton Gorge. Several of the bones were later sent to the Smithsonian Institution at Washington, D. C., where the skeleton was identified as that of an Indian girl. Arrowheads, a spearhead

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[1] Text references are listed on pp. 169-174.

and charcoal have also been reported from Luray Caverns. Hovey[3] reported that moccasin tracks, preserved and protected by shallow water and a thin incrustation of lime, were found near the Hollow Column. He[4] stated that in Kaiser's Cave, 8 miles north of Luray, was found an Indian grave 5 by 8 feet and 8 feet deep, in which 12 bodies were piled, one on top of another. Several of the skulls and bones were embedded in dripstone.

According to tradition the skeleton of an Indian youth was found in Shenandoah Caverns by an early resident of that region. This report has never been verified. It is claimed that several Indian burial mounds occur in the vicinity of these caverns. Legend has it that human bones were found also in Massanutten Caverns. Arrowheads and charcoal were reported at a depth of about 18 inches in the earthen floor of Virginia Caverns.

The Valley of Virginia has long been an important and historic natural thoroughfare. It was the frontier of the colonies in the early settlement of North America and the pioneers in this region were constantly subjected to depredations by the Indians. Many battles of the French and Indian War and several engagements of the Revolutionary War were fought in this section. As the "Granary of the South," the Shenandoah Valley was one of the important battlegrounds of the War between the States. During the successive periods of strife and interrupted development, the numerous caverns of the Valley doubtless offered refuge alike to Indians and pioneers, soldiers and renegades, settlers and transients.

During the War between the States, Virginia Caverns and possibly others were successively occupied by soldiers of both armies. Hundreds of names of the men who camped in Virginia Caverns are inscribed on its walls (Pl. 31B) and lend credence to the many legendary tales that persist through the Valley region regarding the occupancy of other caverns during that period. It is claimed that Battlefield-Crystal Caverns were used as a refuge

by runaway slaves and by deserters from both armies during the conflict. The site of the caverns was one of the battlegrounds and remains of earthen breastworks and artillery emplacements on the property are today pointed out to visitors.

During the War between the States, many Tennessee and Virginia caves were operated by the Confederate Government for saltpeter for the manufacture of gunpowder.[5]

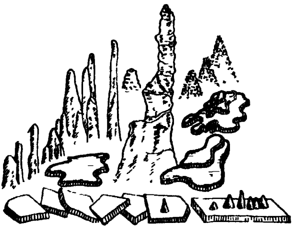
Many stories are told of caves in southwestern Virginia, particularly in Abingdon and Powell valleys, which were used as hiding places by marauding bands of Indians in pioneer days and as headquarters for highwaymen who preyed on the early settlers. Others were used as places of refuge by the early colonists to escape Indian massacres. The records of some of the county clerks are said to have been hid in the locally known caves during war days and other caves are reported to have been used as hiding places for county treasurers in times of insecurity.

Many of the caves of Virginia have been the lair of wild animals. Hovey[6] reported the discovery of skulls of wolves, deer, bears and a panther in Luray Caverns; also the bones of rats, mice, bats, squirrels and raccoons, all of geologically recent and existing species. He likewise remarked on the occurrence of possible bear wallows. Similar features have been reported from some of the smaller caves in Tazewell County and other portions of southwest Virginia. According to Hovey,[7] perfectly white rats with large, protruding eyes have been caught in Count's Cave, 3 miles north of Luray. They are believed to be a modified type of a rat from the outside. Only a small number of bats and few insects of scientific interest have been noted in the caverns of Virginia.

Since discoveries of great scientific interest and value have been made in many caves in the Old World and a few human remains and implements have been found in some American caves, all newly discovered

caves and unexplored portions of caverns already known should be carefully examined for possible relics of ancient human occupation.

It is still a moot question as to whether North America was inhabited by man during the last ice age, although conclusive evidences of glacial man have been found in European and Asiatic caves. Evidence bearing upon this fascinating archæological problem may be found in some cavern.



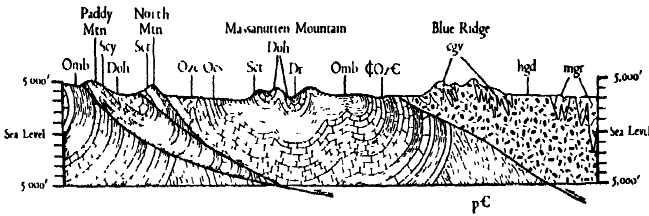
CHAPTER II

Geologic History of the Appalachian Valley

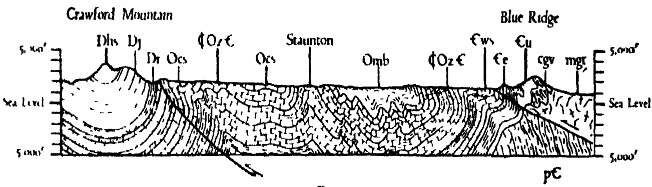
Antecedent Conditions

THE caverns of Virginia occur chiefly along broad arches or anticlines in belts of limestone which trend northeastward in the Valley of Virginia and the Valley Ridges. Their origin is closely related to the geologic history of the region, especially to the kind and structure of the bedrock and to the drainage changes that have taken place during recent geologic time.[8] Because of these genetic relationships, a brief outline of the geologic history of the Appalachian Valley in Virginia will be of interest and value to the reader in understanding the fascinating mysteries of these underground wonderlands.

The beautiful Valley of Virginia and some of the intermontane valleys in the picturesque Valley Ridges section to the west are essentially limestone valleys, being underlain mostly by thick limestone. These valleys have been carved mainly by streams, but to some extent by ground water, out of enormous thicknesses of rocks that formerly covered the area of the present Appalachian Valley, even far above the present mountain crests. The difference in elevation between the crest of Massanutten Mountain and the Shenandoah Valley floor, which is approximately 1,900 feet, represents only a very small portion of the thickness of rocks that has been eroded and carried away by Shenandoah River and its tributaries in carving out the present Shenandoah Valley from the old plateau which occupied this region.



A.



B.

Figure 1.—Geologic structure sections across the northern part of the Appalachian Valley in Virginia. A, Northwest between Woodstock and Strasburg; B, Northwest through Staunton. pꞒ, cgv, mgr, hgd, pre-Cambrian crystalline rocks; Ꞓu, Unicoi sandstone; Ꞓe, Erwin quartzite; Ꞓws, Rome ("Watauga") formation and Shady dolomite; ₵OzꞒ, Beekmantown, Conococheague and Elbrook formations; Ozc, Conococheague limestone; Ocs, Chambersburg and Stones River formations; Omb, Martinsburg formation; Sct, Clinton, Tuscarora (Clinch) and Juniata formations; Scy, Cayuga group; Doh, Oriskany sandstone and Helderberg group; Dr, Romney shale; Dj, Chemung and Brallier ("Jennings") formations; Dhs, Catskill ("Hampshire") formation. (From Geologic map of Virginia: Virginia Geol. Survey, 1928.)

During the early history of this region, in the Paleozoic era, enormous thicknesses of sediments, later consolidated into limestones, shales and sandstones, were deposited in nearly horizontal beds in great interior seas which at successive geologic periods occupied the Appalachian Trough (Tables 1 and 2). The terms Appalachian Trough and Appalachian geosyncline are both applied to the Appalachian region from Canada to the Gulf of Mexico, over which an inland sea extended at different times. Toward the end of the Paleozoic era, during the slow formation of the old Appalachian Mountains by strong lateral pressure and pronounced vertical uplift, this huge mass of sedimentary rocks was highly folded, fractured and displaced by great thrust faults (Fig. 1). Countless zones of weakness, such as joints and belts of crushed and faulted rock, were developed in the limestones.[9]

During and following the late Paleozoic deformation of the Appalachian region, and the later vertical uplift at successive stages in the Mesozoic and Cenozoic eras, many thousand feet of the folded and broken rocks were eroded and carried far away by the prolonged activity of rains, surface streams, ground water and other geologic agents. Hence beds of rock of variable composition and hardness were exposed in long, generally narrow, parallel northeast-southwest belts. Broad, flat-floored valleys were eroded in the areas underlain by the weaker rocks, such as limestone and shale, whereas the more resistant rocks, such as sandstone and quartzite, were left standing as prominent mountain ridges (Pl. 2 and Fig. 1). As a result of several episodes of approximately vertical uplift and consequent intervals of widespread and deep erosion by rejuvenated streams and drainage systems, the present Valley of Virginia and the Valley Ridges were created. These geologic processes required long periods of time, hundreds of thousands or millions of years.

Old Erosion Levels

Certain characteristic topographic features prevail throughout the Appalachian Valley as evidence of the deformation and vast erosion which the rocks of the region have undergone.

Four distinct stages or cycles of erosion are recorded by recognizable topographic levels. The flattish ridge crests and hilltops at each level are remnants of formerly extensive valley floors, each produced by streams eroding the region toward a common plane, not far above sea-level. Regional plains of this type are called peneplains. The peneplains of the Appalachian Valley in Virginia have been described by Stose,[10] and Wright.[11] These erosion levels are shown diagrammatically in Figure 2. The highest and oldest level is apparently marked by the uppermost flattish summits of the Blue Ridge and the highest ridges among the Valley Ridges. These numerous summit areas are but meager remnants of the vast undulatory plain which formerly covered the entire region and from which the present valleys and ridges have since been carved. Due to the great age of this former land surface and the amount of uplift and consequent erosion it has undergone, remnants of this old land surface are not uniformly preserved throughout the Appalachian region. The highest level has been called by Stose[12] the Summit peneplain. The remnants of this old surface, or uplifted peneplain, are now from 3,500 to 4,000 feet above sea-level.

The lowest widespread level is represented by the gently rolling, stream-dissected, solution-pitted floors of Shenandoah Valley and similar valleys west of the Blue Ridge. This youngest peneplain has been named the Valley-floor, or Shenandoah, peneplain. Other local names are used in other divisions of the Valley of Virginia. It varies in altitude from about 600 feet along the Potomac to 2,200 feet at the southern end

of Shenandoah Valley, and 2,600 feet at places in Dublin and Abingdon valleys. It was formed probably during late Tertiary time.

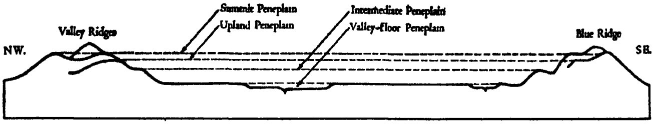


Figure 2.—Ideal profile section across the Valley of Virginia showing erosion levels or peneplain surfaces. (After Stose, G. W., Virginia Geol. Survey Bulletin 23, Fig. 2.)

Between these two distinct erosion levels, or peneplains, occur the Upland peneplain represented by the even-crested summits of several of the mountain ridges in the Valley Ridges section as well as by the broad, rounded tops of the Blue Ridge at an altitude of about 3,000 feet, and the Intermediate peneplain preserved in the even tops of the foothills and the spur ridges of the Blue Ridge and Valley Ridges at an altitude of about 2,200 to 2,300 feet.

Prominent hills and elongate ridges, termed monadnocks, rising 100 to 500 feet above the floor of the Valley, remain also as partially reduced remnants of former surfaces. Such monadnocks persist chiefly because they are composed of rocks of superior resistance to erosion or they were far from the main streams in the region. One of the most outstanding of the larger monadnocks is Massanutten Mountain (Pl. 2).

Drainage Changes

During each erosion cycle definite drainage systems were established in the Appalachian Valley. The interruption of each erosion cycle by vertical uplift and warping produced some modification of the established drainage so that the present surface streams do not follow the drainage

lines of former geologic times. These changes are shown by numerous abandoned stream channels, many wind gaps and stream courses athwart high ridges. The principal changes in the drainage of the Shenandoah Valley and the drainage patterns which prevailed in each cycle are briefly outlined below from a paper by Watson and Cline.[13]

During the formation of the Summit peneplain, the area now occupied by the Blue Ridge and the Valley Ridges was worn down close to sea-level. Several rivers, including the Potomac on the north and the Rockfish to the south, flowed southeast across the future Shenandoah Valley and the Blue Ridge. The tributaries to the main eastward-flowing rivers were developed at right angles, most probably along the strike of the weaker beds of rock west of the present Blue Ridge.

The first erosion cycle was ended by a more or less vertical uplift, according to Stose[14] probably in Cretaceous time, and the streams, with their energy thus renewed, began to deepen again their channels, excavate new valleys and carry away the bedrock. It was probably during the second erosion cycle that the resistant rocks, which covered the weaker limestones of the region, were cut through and the first important recorded adjustments and changes in stream courses occurred. Upon reaching the less resistant limestones, the stronger streams deepened their channels more rapidly than the weaker ones or those flowing across resistant sandstones. As a result of the more rapid headward extension and down-cutting of their valleys, the stronger streams undercut and captured the tributaries and headwaters of the smaller and weaker streams. It is thought that three river systems persisted in the Shenandoah Valley region at the end of this second erosion cycle. They were the Potomac, Goose Creek, which formerly occupied Manassas Gap, and the Rockfish which once cut through the Blue Ridge at Rockfish Gap.

Another vertical uplift brought the second erosion cycle to an end,

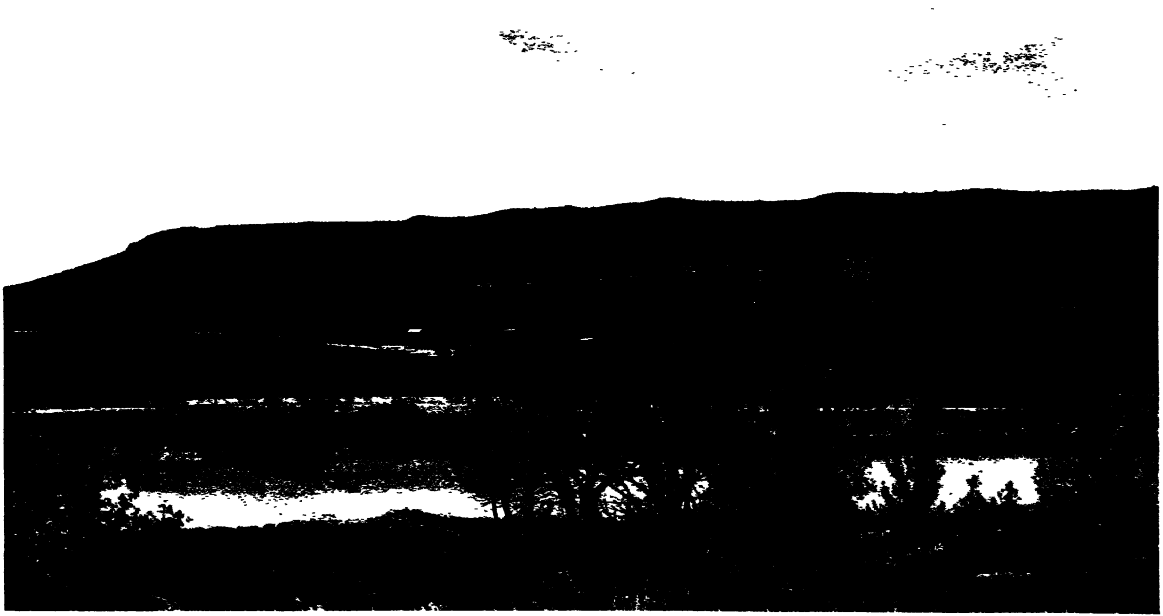


Plate 2. Massanutten Mountain, west of Luray, a monadnock on the Valley-floor peneplain. The mountain rises about 1,900 feet above the Valley floor to an elevation of 3,000 feet. (Photograph by W. K. Rhodes.)

again rejuvenated the streams, and thus commenced a third period of erosion. The Potomac and Goose Creek drainage systems were rivals during the early part of this cycle. Potomac River, being the more powerful stream, cut a wider and deeper gap through the Blue Ridge at Harpers Ferry and thus deepened its channel more rapidly than did Goose Creek at Manassas Gap. Toward the latter part of this cycle, the young Shenandoah, by headward extension to the south, captured the Goose Creek system at Manassas Gap. This was probably the last important capture in the development of the present Shenandoah drainage system.

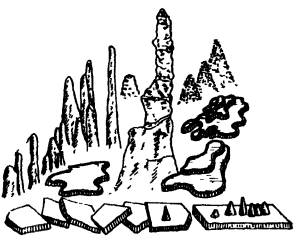
The third erosion cycle was brought to an end by a third uplift of the region, and the present cycle was begun, during which the Valley-floor peneplain has been dissected in places into a veritable mosaic of hills and valleys. Only in a few places, however, is the Valley-floor peneplain maturely dissected. The major streams have become strongly entrenched since the beginning of the present cycle and are now flowing in meandering courses like North Fork of Shenandoah River in the vicinity of Woodstock (Pl. 47), 200 to 300 feet below the Valley-floor plain.

Origin of the Caverns

The caverns of the Valley of Virginia have doubtless been formed chiefly during the last erosion cycle which commenced with the vertical uplift of the present Valley-floor during late Tertiary time. This uplift of at least several hundred feet, which possibly continues imperceptibly, has so increased the velocity of the streams that they have partly dissected the Valley-floor peneplain into gently rolling uplands and have cut their channels below the old broad flood plains.

As the streams cut more deeply into the uplifted Valley-floor peneplain, the belts of weak, soluble limestone were more fully exposed to

erosion. Because of the folding and fracturing of the rocks and the solubility of limestone in rain and ground water, some of the surface waters penetrated in places the underlying limestone. Through the slow development of underground channels by solution and stream erosion, caverns of considerable size were developed, mainly along the strike of the limestones. The continued down-cutting of surface streams and the consequent lowering of the water table and of ground-water circulation caused cavern channels and rooms to be developed at several levels.



CHAPTER III

Developed Caverns

THE location of the developed caverns of Virginia is shown in Figure 3 and is given in detail in the descriptions of the individual caverns. Each of the caverns is accessible by automobile over well-marked, hard-surfaced roads from the Lee, or Valley, Highway (Route 11). They may be reached by short and interesting scenic drives from the larger towns of the Valley, in which the visitor will find comfortable and pleasant accommodations.

The caverns are open to visitors day and night throughout the year and courteous and efficient guide service is provided at all times. The temperature of the caverns of Virginia varies but slightly through the year, the average being from 50° to 54° F. Gravel or concrete walks provide safe and comfortable passages through the developed portions. Steps and stairways of concrete and wood are used where necessary. Guard rails and rock walls fortify all danger spots. One may wear ordinary street clothes. During the summer months the caverns are delightful retreats from the midday sun and a jacket or sweater is not uncomfortable.

Rest rooms and inviting camping sites are provided at each cavern and at several, cottages, inns or picturesque lodges and restaurants offer attractive accommodations and refreshments. Outdoor sports and other recreational facilities are available amid picturesque surroundings.

The general arrangement of the passageways and rooms is shown on sketch maps, made by the writer from a compass survey, accompanying the descriptions of the individual caverns. Distances were paced.

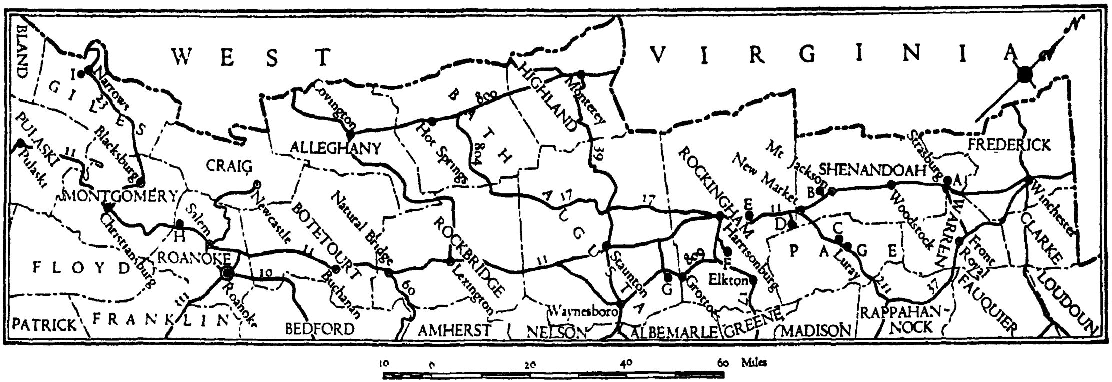


Figure 3.—Map showing location of developed caverns in the Valley of Virginia. A, Battlefield-Crystal Caverns; B, Shenandoah Caverns; C, Luray Caverns; D, Endless Caverns; E, Virginia Caverns; F, Massanutten Caverns; G, Grand Caverns; H, Dixie Caverns; I, Giant Caverns. Numbers designate highways.

Table 1.—Features of Developed Caverns in Virginia

Caverns	Geologic horizon at entrance[a]	Bedrock in Caverns		Approximate Elevation (Feet)			Known levels	Approximate length of tour (Feet)
		Strike	Dip	Entrance	Highest point	Lowest point		
Battlefield-Crystal	Chambersburg formation	N. 60°– 65°E.	12°– 14°SE.	710	[c] 690	635	3	1,250
Dixie	Elbrook limestone	N. 70°– 73°E.	30°– 34°SE.	1,170	[d] 1,275	1,150	3	1,250
Endless	Stones River limestone[b]	N. 35°– 45°E.	14°– 20°SE.	1,145	[e] 1,125	1,080	3	7,000
Giant	Stones River limestone	N. 60°– 70°E.	20°– 35°SE.	1,960	[f] 1,980	1,860	3	2,500
Grand	Conococheague limestone	N. 18°– 20°E.	65°– 85°SE. 80°–85°NW.	1,215	[g] 1,285	1,140	4	3,800
Luray	Beekmantown dolomite	N. 45°E.	25°– 35°SE.	972	[h] 1,025	902	4	7,000
Massanutten	Stones River limestone	N. 45°– 50°E.	60°– 68°SE.	1,650	[i] 1,670	1,635	2	1,250
Shenandoah	Conococheague limestone	N. 45°E.	36°– 50°SE.	1,035	[j] 1,030	941	3	3,900
Virginia	Stones River limestone	N. 45°– 55°E.	12°– 16°SE.	1,270	[k] 1,260	1,200	2	2,500

[a]Identified by Dr. Charles Butts. [b]Stones River limestone includes the Mosheim and Lenoir limestones. [c]Ceiling in Tower Room. [d]Ceiling in Auditorium. [e]Ceiling in Oriental Palace. [f]Ceiling in Giant's Hall. [g]Ceiling in Peanut Gallery. [h]Ceiling of Dante's Inferno. [i]Ceiling in Star Chamber. [j]Ceiling in Napoleon's Mausoleum. [k]Ceiling in Cliff Dwellers' Alcove.

Elevations were obtained by aneroid barometer and are, therefore, approximate. The identification of the particular limestones which contain the accessible caverns, that is, their geologic horizons, was made by Charles Butts of the United States Geological Survey which is making, in coöperation with the Virginia Geological Survey, a study of the geological formations in the Appalachian Valley in Virginia. These formations are shown in Table 3 (pp. 136-139).

In the following account no attempt has been made to describe all of the points of interest. The characteristic features of each cavern are discussed at length and particular reference is made to striking differences. Detailed information regarding the discovery and history of the caverns and illustrated booklets containing descriptions of them may be obtained from the respective cavern headquarters. The most prominent and picturesque travertine deposits and the outstanding "formations" are pointed out and described by the guides.

Comparative data on the caverns are given in Table 1 and the composition of limestone from each is shown in Table 4. Copies of the topographic maps covering the areas in which the caverns occur may be obtained from the Virginia Geological Survey, University, Virginia, or the U. S. Geological Survey, Washington, D. C., at 10 cents each. An index sheet to these maps will be furnished upon request.

Battlefield-Crystal Caverns

Battlefield-Crystal Caverns are on the east slope of Hupps Hill about 1 mile north of Strasburg in northern Shenandoah County (Fig. 3). These caverns are in the area shown on the Winchester topographic map. The entrance is 300 yards west of Route 11. It is claimed that these caverns were discovered in 1755, which would make them among the oldest known caves in Virginia.[15] They are the most northerly devel-

oped caverns in Virginia and are the first ones reached in driving south through the Shenandoah Valley.

There is considerable legend attached to the early history of Battlefield-Crystal Caverns, which were originally known as Hupps Cave and later as Crystal Cave. It is said that soon after their discovery they were visited by the early Dutch settlers of the Valley region, who lighted the dark chambers with tallow candles or torches. Stories persist that the caverns were often used as a refuge by slaves and the settlers alike and by deserters from the two armies during the War between the States. Credence is given these stories by the remains of infantry breastworks and old artillery emplacements to be seen on the caverns property which was the scene of the Battle of Cedar Creek. The caverns were cleaned out, lighted by electricity and first opened to the public in 1922.

The entrance to the caverns is by a concrete stairway from a small frame house (Fig. 4). The elevation at the top of the stairway is about 710 feet and that of the floor at the stone fireplace on the west side of the Entrance Room is about 690 feet. The part open to visitors consists essentially of a series of elongate chambers connected by narrow passages excavated on three distinct levels. The complete tour is about half a mile. Since the formal opening in May, 1922, several new side channels have been found. Recent explorations have revealed another chamber at a lower level, said to contain more travertine formations than have been found in any other part of the caverns. There are a number of sink-holes on the property surrounding the entrance and it is probable that underground channels from several of them lead into undiscovered rooms. The caverns as a whole are in the Chambersburg formation of Ordovician age (Fig. 5 and Table 3).

Battlefield-Crystal Caverns differ from the other Virginia caverns principally in the narrow width and relative depth of their channels,

which were mainly excavated along almost vertical joints, and in their lack of travertine deposits such as characterize and beautify the other developed caverns of Virginia. Only in the alcoves developed at intervals along the main passages, generally at the junction of tributary channels, are found secondary formations, such as stalactites and stalagmites, formed largely by the seepage of water along prominent joints and through the old, small tributary channels. A few curiously shaped stalactites, masses of dripstone and lifelike images are found on the walls and ceilings of certain chambers. They occur principally at places where surface seepage has probably been favored by the development of enlarged crevices and connecting channels.

Among the fantastic shapes that greet the spectator at the entrance to the Vista are the Brontosaurus and Giant's Coffin. The Brontosaurus is a fantastic flowstone form resembling the ancient reptilian monster after which it has been named. Giant's Coffin, on the contrary, is a huge six-sided block of limestone which has undoubtedly fallen from the ceiling at some remote period, to be draped by the percolating waters with a sombre flowstone pall. Another realistic flowstone formation is the Frozen Cascade (Pl. 3).

The rooms and chambers are not developed in the continuous longitudinal pattern which is so pronounced in other caverns of Virginia but occur chiefly along intersecting joints where solution and stream action have been most active. Some have been developed at different levels along enlarged parallel joints, as the Hall of Masonry and the Ball Room, where two streams occupied parallel channels along the strike of the limestone. Others occur along the dip of the beds of limestone where conditions were more favorable for lateral enlargement of the passage, as in the Vista.

The Vista (Pl. 4) was probably the first underground channel formed

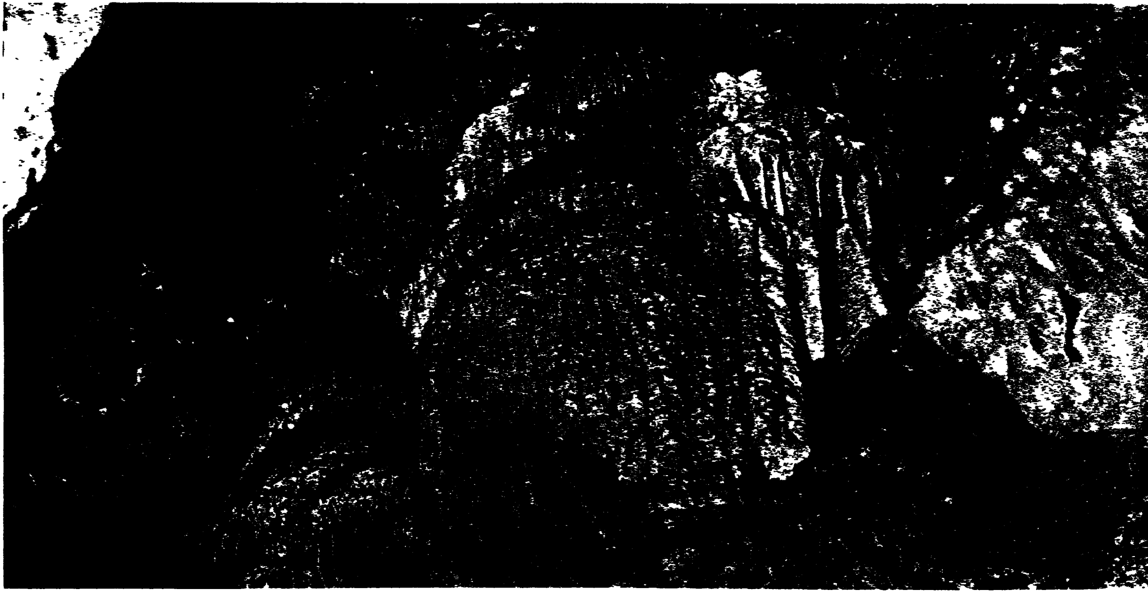


Plate 3. The Frozen Cascade, a realistic flowstone deposit in Battlefield-Crystal Caverns. The height of the Cascade is about 12 feet. To the left is an abandoned channel. (Courtesy Marken & Bielfeld, Inc.)

Plate 4. The Vista in Battlefield-Crystal Caverns. Looking towards the Giant's Coffin from Narrow Bridge pass. The bridge spans an intersecting channel. (Courtesy Marken & Bielfeld, Inc.)

and was probably excavated by surface waters which, entering the sink-hole about 50 feet northwest of the entrance, excavated a more or less lateral passageway along a bedding plane in the limestone. Some of the roughly parallel, elongate, transverse side channels were formed along strike joints by water from the original channel (Fig. 4). The excavation of other linear and inclined channels along the same or similar parallel joints was probably aided by waters from several of the sink-holes which occur at various distances west and southwest of the entrance.

The Ball Room, the largest and lowest chamber open to the public, is about 90 feet long and has a maximum width of 30 feet. The elevation of the floor is about 635 to 640 feet, being lowest at the southwest end—65 to 70 feet lower than the entrance—and more than 100 feet below the crest of Cave Hill. At the southwest end, 6 to 8 feet lower, is Crystal Pool, the lowest part of the caverns, said to feed Hupps Spring, at the base of Hupps Hill, a short distance southeast of the caverns.

From the southwest end of the Ball Room a narrow, muddy passage as yet but partly opened leads northwest, intersecting and crossing a narrow passage which extends southwest from the rear end of the Hall of Masonry. Both channels extend some distance into the limestone beyond their intersection as is indicated on the sketch map (Fig. 4). Neither is more than 4 feet wide and both are about 12 feet high near their intersection. The muddy floor is from 6 to 8 feet lower than the floor of the Ball Room, or about the same elevation as Crystal Pool. Numerous small, nestlike depressions occur in the limestone walls on either side of both of the channels near their intersection. It is along the narrow channel which extends southwest from the Hall of Masonry that the new room containing the many travertine deposits referred to above has recently been discovered. This part of the caverns has not

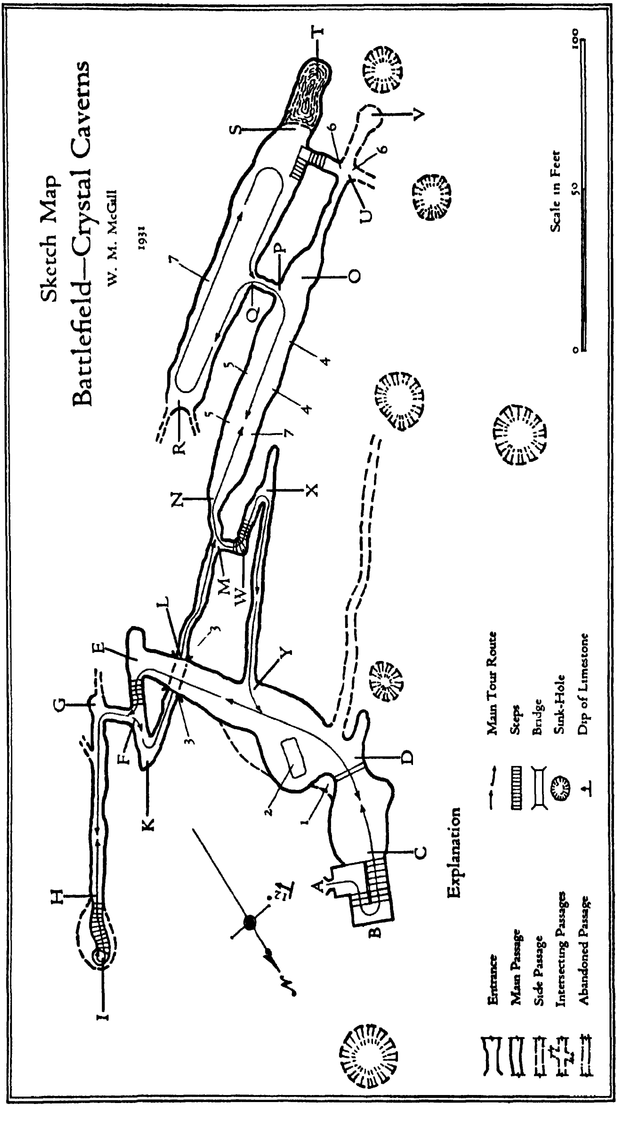


Figure 4.—Sketch map of Battlefield-Crystal Caverns

Figure 4

EXPLANATION

A-C. Entrance Stairway.
C-D. Entrance Room.
D-E. The Vista.
E-K-L. Flatiron Corridor.
F-G. Short Tunnel.
G-H. The Lane.
H-I. Tower Room.
K-L-M. Subway.
(Flatiron Corridor.)
M-N. Crooked Lane.
N-O. Hall of Masonry.
P-Q. The Pass.
R-S. The Ball Room.
S-T. Crystal Pool.
S-U. New Passage.
U-V. New Room.
M-W-X. The Incline.
X-Y. Narrow Passage.

1. The Brontosaurus.
2. Giant's Coffin.
3. Frozen Cascade.
4. Cobbled floor.
5. Calcite veins.
6. Nestlike holes and basins in walls.
7. Pebble marks.

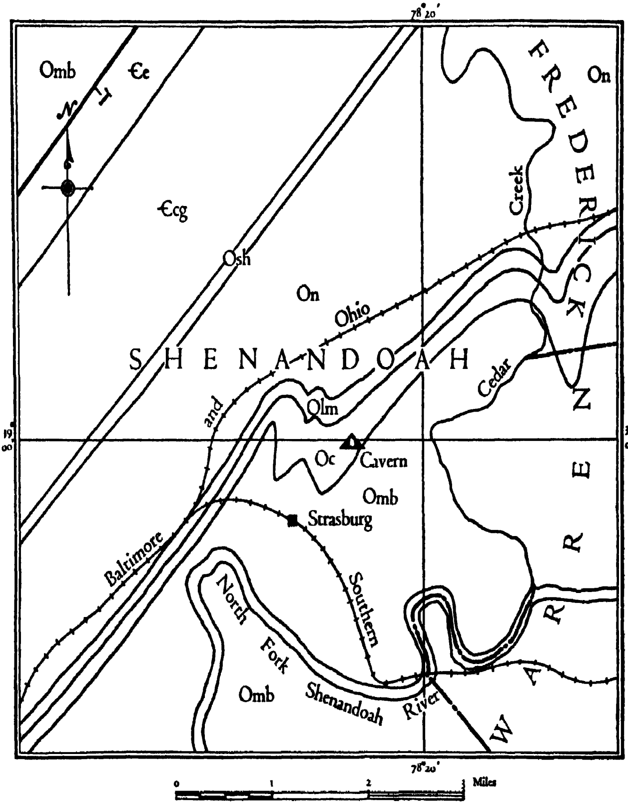


Figure 5.—Geologic sketch map of the environs of Battlefield-Crystal Caverns. (By Charles Butts.) Ꞓe, Elbrook dolomite; Ꞓcg, Conococheague limestone; Osh, Stonehenge limestone; On, Nittany dolomite; Olm, Stones River (Mosheim and Lenoir) limestones; Oc, Chambersburg formation; Omb, Martinsburg formation.

yet been opened to the public but probably will be in the near future.

The Tower Room, also called the Whirlpool Room, is the highest part of the caverns. The ceiling is about 690 to 695 feet above sea-level. It is thought that its highest point is only 15 to 20 feet beneath the surface.

The Hall of Masonry derives its name from the many parallel veins of calcite which cut the walls and ceiling of this chamber at more or less regularly spaced intervals. They vary in width from 1 to 3 inches and are nearly vertical.

In addition to the narrow, generally deep, type of passages, certain features of these caverns illustrate the prominence of stream erosion in their formation. Basin-shaped or nestlike depressions are found along the walls in several places, perhaps more prominently in the Hall of Masonry and in the recently opened side rooms. In other parts of the caverns the walls and floors are distinctly spotted with marks made by pebbles in swirling water or in small whirlpools formed by the convergence of two channels. In the Hall of Masonry and at one or two other places in the caverns the floor is covered to a depth of several inches with a layer of rounded pebbles and nodular concretions deposited in the channel by flowing water. At such spots the floor resembles a cobblestone pavement.

Several pretty scenic views are to be had from Hupps Hill. Signal Knob rises to a conspicuous height on the north end of Massanutten Mountain a few miles to the east. The picturesque rocky columns at Waterlick Gap of Passage Creek are within a short and pleasant drive from Strasburg. Snickers Gap and the proposed northern entrance to the Shenandoah National Park area are several miles farther east.

Dixie Caverns

Dixie Caverns are 7 miles southwest of Salem in the northeast side

of Cave Hill, a flanking ridge of Fort Lewis Mountain, near the western boundary of Roanoke County (Fig. 3). They are in the area shown on the Salem topographic map. The entrance is within 200 yards of the Lee Highway (Route 11), from which a sand-gravel road leads to a rustic lodge in an inviting mountain meadow. A small stream winds through the wooded meadow a short distance northeast of the caverns entrance to discharge into the picturesque Big Bend of Roanoke River just across the highway. According to local legend, the existence of Dixie Caverns has been known for 75 years or longer, though it was not until 1922 that they were opened to the public. They are the largest known caverns in the Roanoke region.[16]

Entrance to the caverns is through a naturally carved passage which leads into the hillside a short distance to the rear of the lodge at an elevation of about 1,170 feet or about 45 feet above Roanoke River. The complete tour of the developed portions is approximately a quarter of a mile and can be conveniently made in about 50 minutes.

Dixie Caverns consist of a continuous series of narrow passages and large chambers excavated on three levels, with several intersecting and cross channels and a number of partly explored side channels leading, at intervals, from the main corridors. There is at least one known undeveloped level above the present highest tour passage, and indications of intermediate channels between these may be seen at several places. Most of the corridors have been excavated along joints in the general direction of the northeast strike of the limestone, with chambers or alcove-like enlargements occurring at the intersection of cross channels (Fig. 6). These caverns are in the Elbrook limestone of late Cambrian age (Fig. 7 and Table 3).

From the entrance a barren passage leads southwesterly for about 15 feet to a corridor which, excavated almost at a right angle, extends

northwesterly for about 50 feet. In this passage, Main Corridor, are seen the first travertine deposits in these caverns, small clusters and rows of stalactites, occurring along a longitudinal joint in the center of the ceiling. At the northeast end, or entrance, of the corridor, is a small alcove formed by a tributary channel from a higher course.

At the northwest end of Main Corridor, a short passage which bears nearly south leads to a concrete stairway by which one ascends some 35 feet along an inclined connecting channel to the second (main tour) level. Examples of the amount of broken rock and transported material deposited at such intersecting passages by the down-cutting waters may be seen on each side of the stairway. At such junctions the main or connecting channel is frequently choked or filled by transported fragments thickly coated with flowstone. Opposite the base of the stairway there is a small oval alcove lined with a blanket deposit of colorful reddish and brownish flowstone.

Several strange and realistic statuettes are here pointed out by the guide. As one looks upward along one of the inclined channels he may see part of an abandoned upper passage extending southwestward for 60 feet or more, with its ceiling about 70 feet above the floor of the entrance level.

From the top of the stairway, a passage to the left leads to the Auditorium, the largest and most spectacular chamber in the caverns, whose floor level is about 5 feet above the top of the stairway. This is a roughly oval room about 40 by 50 feet with its ceiling some 65 feet above the floor. It is a splendid example of a chamber formed at the junction of channels on different levels. The right wall, along the passage by which one enters from the stairway, is profusely covered with a decorative deposit of flowstone known as the Cascades (Pl. 5A).

Around portions of the walls, rows of fluted, fin-shaped, drapery-

like stalactites hang from terrace-like masses of flowstone. The ceiling is profusely adorned with stalactites and draperies which vary in size and shape. Rows of slender stalactites fringe small fissures extending across the ceiling along the strike of the limestone. Clusters of odd-shaped stalactites and groups of intergrown fin-shaped and cone-shaped draperies and stalactites appear here and there.

Two large broken blocks of limestone nearly fill this room. These huge masses are covered with a blanket of flowstone from which at intervals rise several round-topped stalagmites 2 to 3 feet in height. Along the right (northeast) wall, opposite the two broken masses of rock, are the Organ and Cathedral, two realistic, massive stalagmitic and drapery formations which rise to prominent heights. Several tower-like stalagmites project like bell towers above the Cathedral. Both the Cathedral and the Organ are further adorned with terraces of flowstone and tiers of fluted silver and bronze-colored draperies. A small abandoned side channel extends back of these formations in the direction of the Spillway.

From near the center of the Auditorium, a path leads to the right (southwest) around one side of the Cathedral. Descending some 3 feet by concrete steps, one enters Narrow Passage which extends southwesterly for about 40 feet. The floor has a slight slope to the southwest. This passage was cut through the mantle of transported material deposited on the floor of the Auditorium and benches of this material remain on either side of the passage. Several graceful bush-shaped and hedge-shaped stalagmitic and flowstone formations adorn the benches. On the right there is a narrow steep side channel which leads from the Auditorium back of the Cathedral and the Organ to the Spillway.

At the end of Narrow Passage, the path turns abruptly to the right and leads down a flight of steps to the Spillway. The floor is here about

Plate 5. A, The Cascades, attractive tiered and fluted flowstone deposits decorating the walls of the Auditorium in Dixie Caverns.

B, The Magic Mirror, a small lake on a suspended balcony in Dixie Caverns. The balcony extends across the room.

Plate 6. The Bell Canopy in Dixie Caverns. The flowstone-coated balconies are similar to those in the Lake Room.

6 feet below Narrow Passage and it is at this point that the above-mentioned side channel leads into the Spillway.

The Spillway is one of the most interesting corridors in Dixie Caverns and is a very good example of an inclined connecting channel. It extends from the steps at the end of Narrow Passage about 60 feet in a general southwest direction, the far end being some 16 feet lower than the entry. This corridor is about 7 feet high and 6 to 10 feet wide. Of especial interest are the rows of wavelike corrugations of travertine variously termed lily pads, pie crust or basin rims which occur on the steeply sloping floor. The formation of these interesting features is described under "Travertine Deposits" in Chapter V. The walls and ceiling are practically barren of travertine deposits.

At the end of the Spillway one turns sharply to the left, descends several feet through a narrow passage with a distinctly stuccoed-appearing ceiling and turns again to the right, passing some 35 feet through the Lane, in a westerly direction to the Lake Room. This room is one of the prettiest chambers in Dixie Caverns and offers a most interesting picture of travertine deposits. It is about 20 feet wide and about 18 feet across from front to rear, with its ceiling only 8 feet above the floor. A terrace or bench, about 4½ feet high, extends across the rear and around two sides of the room, forming a picturesque gallery. The top is covered with a thin, ledgelike sheet of flowstone from which rise slender and graceful stalagmites. Clusters of white and pink stalactites hang from the ceiling and in several places columns formed through the union of stalactites and stalagmites support small suspended balconies which appear to hang miraculously in mid-air.

Near the center of this chamber part of a projecting ledge of travertine extends some 2 feet or more beyond the terrace. Through the drip of percolating waters upon it, a corrugated basin rim was formed, within

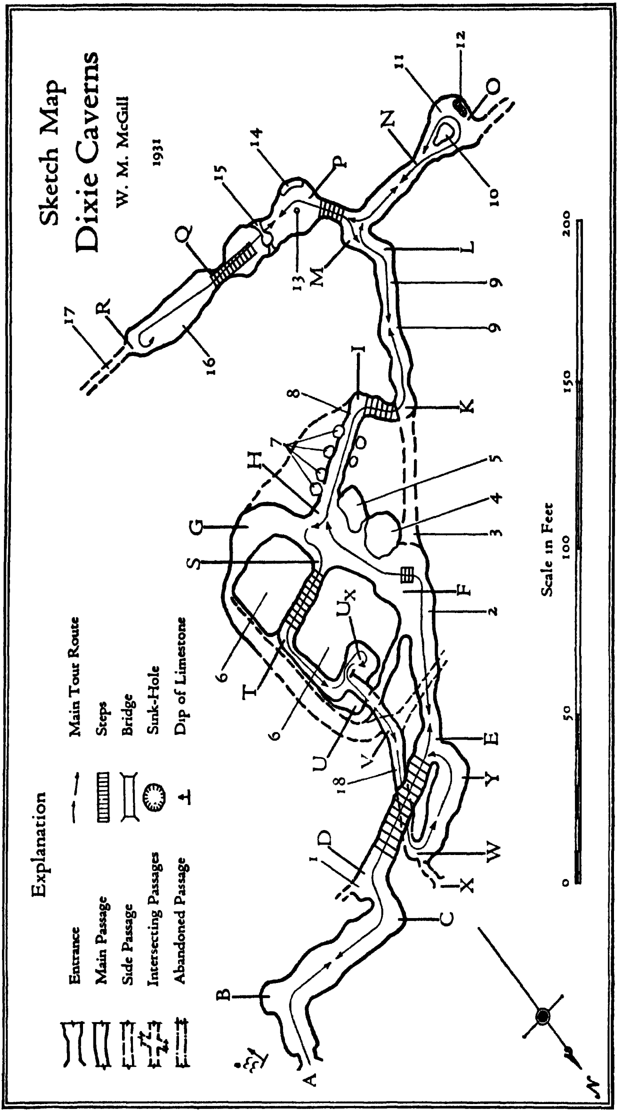


Figure 6.—Sketch map of Dixie Caverns

Figure 6

EXPLANATION

A-B. Entrance Hall.
B-C. Main Corridor.
C-D. Short Passage.
D-E. The Ramp.
E-F. The Colonnade.
F-G-T-U. The Auditorium.
H-I. Narrow Passage.
I-K. The Stairway.
K-L. The Spillway.
L-M. Tunnel Pass.
M-N. The Lane.
N-O. The Lake Room.
M-P. The Cellar Stairs.
P-Q. The Canopy Room.
Q-R. The Gallery.
S-T. The Attic Stairs.
T-U. The Attic.
U_x. Observation Platform.
U-V-W. Skyland Trail.
W-Y. Reception Hall.
X. Original (Discovery) Entry.

1. Miniature Theatre.
2. The Cascades, flowstone and draperies.
3. Miniature Indian Village.
4. The Organ.
5. The Cathedral.
6. Broken limestone blocks.
7. Hedge stalagmites.
8. Benches and undercut banks.
9. Wavelike basin-rim corrugations.
10. Clay bulwark.
11. Overhanging balconies.
12. Mirror Lake.
13. Hitching Post.
14. Upper Berth.
15. Bell Canopy.
16. Bacon-strip draperies.
17. The Curio Gallery.
18. The Cornfield.

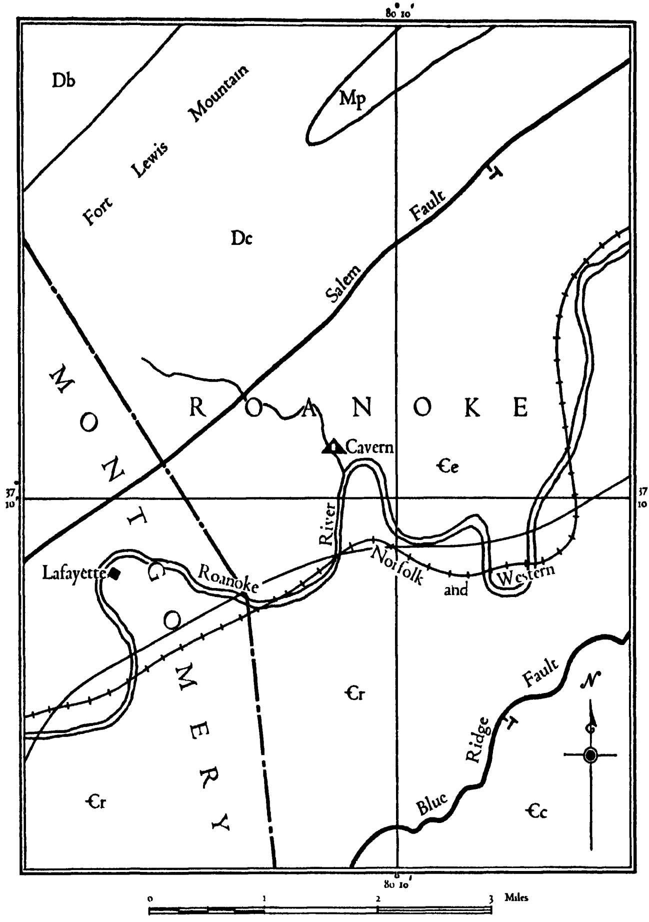


Figure 7.—Geologic sketch map of the environs of Dixie Caverns. (By H. P. Woodward.) Ꞓc, Chilhowee group (Erwin quartzite, Hampton shale, Unicoi sandstone); Ꞓr, Rome ("Watauga") formation; Ꞓe, Elbrook limestone; Db, Brallier shale; Dc, Chemung formation; Mp, Price formation.

which occurs Magic Mirror, an entrancing lakelet (Pl. 5B). In this lake are reflected beautiful pictures of the gracefully adorned ceiling of the Lake Room. Beyond and to the right of the lake a small, undeveloped passage extends some 30 feet or more into the limestone, its far end being some 8 to 10 feet below the floor of the Lake Room.

At the east (entrance) end of the Lane, a narrow passage leads to the right, through which one descends some 8 feet by concrete steps into the Canopy Room, one of the "show spots" of Dixie Caverns. This is a circular room about 20 feet in diameter with a height of from 8 to 12 feet. Its floor has the lowest elevation, about 1,150 feet, of any developed part of the caverns. In the center of the Canopy Room, a single graceful stalagmite, which resembles a hitching-post, rises slightly more than 4 feet above the floor. It has a diameter of about 5 inches and a circumference, at its base, of about 19 inches. Around the right side of this chamber there extends an overhanging shelf which realistically suggests its name, the Upper Berth. This shelf is a portion of a former flowstone floor which, as the channel through this chamber was deepened, became first a bench and then as the material beneath it was dissolved and carried away, a projecting shelf (Pl. 6).

The Bell or Canopy is a picturesque, dome-shaped deposit of stalagmite and flowstone built on a flowstone sheet or ledge, similar to the Upper Berth (Pl. 6). Other examples of flowstone sheets and shelves, now exposed as suspended balconies or overhanging ledges, occur in Canopy Room. It is probable that most of these ledges represent a deposit of flowstone formed on the floor of the original channel through this chamber, which connected the Curio Room with the Lane.

From the Canopy Room one ascends by a flight of steps to the Curio Gallery, an interesting corridor some 15 feet above the Canopy Room, which extends eastward for 80 feet. From the ceiling project some

odd-shaped groups of stalactites and several bacon-strip draperies. Portions of old channels, long since abandoned, may be seen in this ceiling. Several abandoned side channels, a few of them filled with small stalactites and stalagmites, occur along the side walls. At the far end of the Gallery a shallow, undeveloped channel extends some 60 feet eastward into the bedrock. The gracefully arched ceiling is profusely adorned with slender snow-white stalactites affording one of the prettiest scenes in the caverns (Pl. 36B).

Returning to the Auditorium, one ascends by a stairway between the two large fallen blocks to the Balcony, a small observation platform on top of the largest rock mass. From here is obtained an impressive and unequalled view of the excavation of cavern channels at different levels. The intersection of channels and the development of rooms at such intersections are graphically shown from this vantage point, as from here one may see portions of channels or passages excavated on four different levels.

From the Balcony one follows a circuitous passage to the Reception Hall through which the path leads some 45 feet southwest to the stairway by which entrance to the Auditorium was gained. Descending the stairway the main path is retraced to the entrance. The discovery or original entry passage leads from a point high on Cave Hill into the winding passage at a point near the entrance to the Reception Hall.

Endless Caverns

Endless Caverns are located on the northwest slope of an anticlinal spur ridge flanking Massanutten Mountain on the west, in the area shown on the Woodstock topographic sheet. They are about 3 miles south of New Market and about 2 miles east of the Lee Highway (Route 11) from which they are accessible by a hard-surfaced road (Fig. 3).

Discovered in 1879 and a portion shown for a few years thereafter to those curious enough to investigate them, these caverns were formally opened to the public under the present management in 1920. Since then they have been visited annually by large numbers of visitors from all over North America.

The complete tour comprises about 1¼ miles of passageways through a series of connecting rooms, galleries and narrow corridors in a general north-south or northwest-southeast direction, mainly on two levels (Fig. 8). About a fourth of the developed portion or that part between the entrance and the Marine Corridor consists of a series of looped and connecting channels and rooms having a general northwest-southeast alignment. The floors of various parts of this section, being on two levels, vary as much as 60 feet in elevation. From the southeast end of the Alpine Pass, which adjoins the Marine Corridor, a continuous series of rooms and passages of varying lengths extends slightly west of south on approximately the same level, for a distance of about 1,600 feet. Here at the south end of the developed part of the caverns occurs another looped or circuitous passage, excavated partly by Nature and partly by man.

The longer series of passages extends in a more northerly direction than the main corridors of the other caverns of Virginia. They are excavated along a group of connecting joints, which were most probably produced by folding and faulting of the rocks during an earlier stage. Grasty stated, at a meeting of the Virginia Academy of Science in 1930, that "In this particular cavern [Endless], better than any other, may be seen all the evidences of folding in their relation to the genesis of caverns and they can here be studied and observed to best advantage." The origin of these caverns and many of their striking features have been described by Reeds[17] and Edwards[18]. The caverns are in the Stones

River (Mosheim and Lenoir) limestone of Ordovician age (Fig. 9 and Table 3).

Undeveloped or partly explored side channels along the strike of the limestone or joints at right angles to it extend from or cross the main corridors at frequent intervals. Relatively short and narrow branching and converging channels occur at several places, chiefly as connecting passages between some of the larger rooms. A channel of unknown extent, through parts of which a stream now flows, occurs at a level about 90 feet below the floor of Solomon's Temple. Beneath the Explorers Passage at the end of the main tour, near Diamond Lake, a part of this or a similar lower channel is found at a depth of about 100 feet. It is claimed that no end has been found to these lower channels and new openings or rooms are reported from time to time by exploring parties.

Unusual and bizarre groups of travertine formations appear in places throughout these caverns and there are numerous "show spots" in many of the larger rooms or corridors which are worth a visit on their own account. Probably the most attractive are the massive flowstone deposits, such as the Snowdrift (Pl. 8 A) and Chattahoochee Falls.

The most interesting features of these caverns are perhaps the curiously etched designs in the ceilings and walls of certain rooms and corridors some of which probably resulted from solution or leaching of the bedrock and others, perhaps, from ripple-like movements or gentle periodic agitation of the surface of standing water.

Other features indicative of mechanical erosion by silt, sand, pebbles and other abrasive material carried by the streams are remarkably well preserved, such as odd-shaped, etched, and irregularly rounded and polished projections of limestone of variable lengths, circular eroded stream courses, and troughlike furrows in the ceilings, nestlike holes,

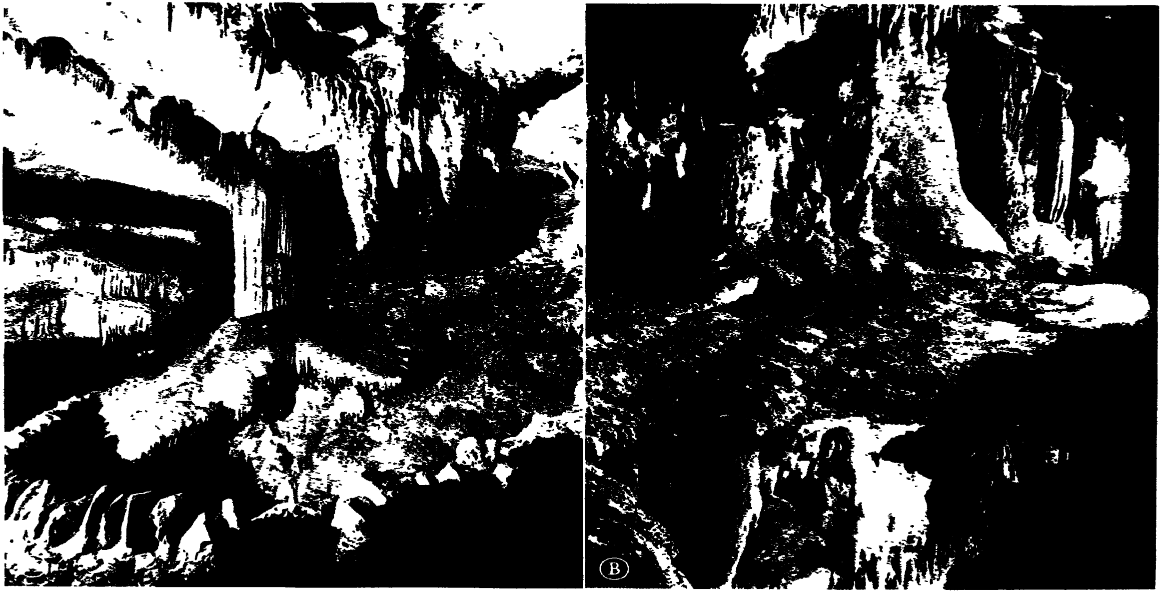


Plate 7. A, Connecting channels and flowstone deposits in Endless Caverns. Stalactite-fringed ceiling rifts and undercut banks in Solomon's Temple. A small stream flows 90 feet below the rock-walled opening.

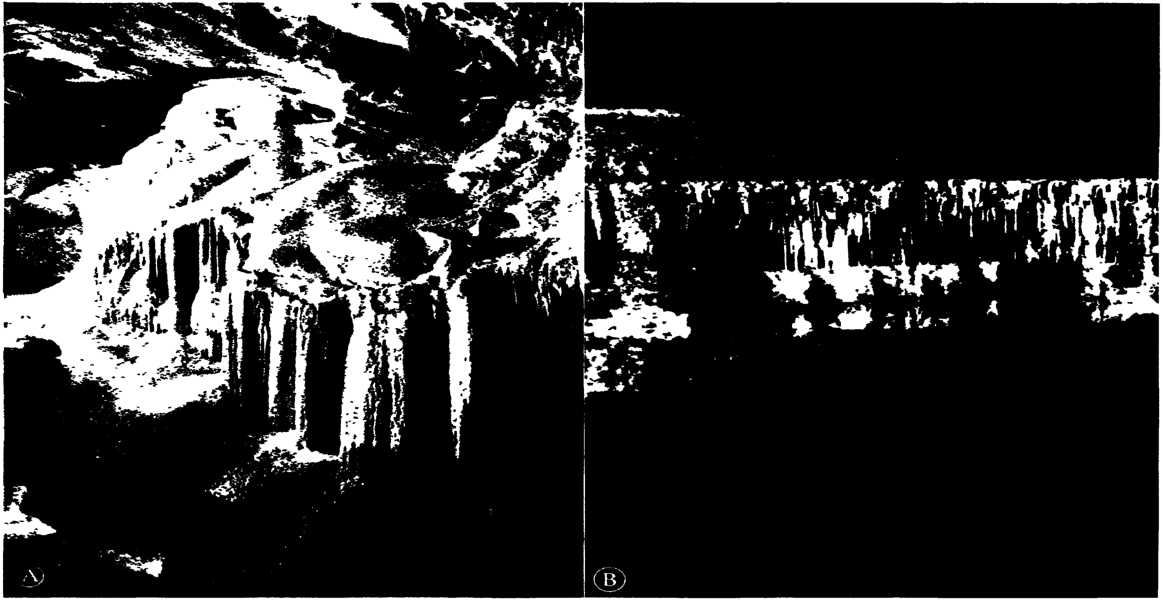


Plate 8. A, The Snowdrift, a mass of flowstone in Endless Caverns. The height of the Snowdrift is about 20 feet.
B, Diamond Lake with overhanging stalactites in Endless Caverns. Deposits of travertine around the base

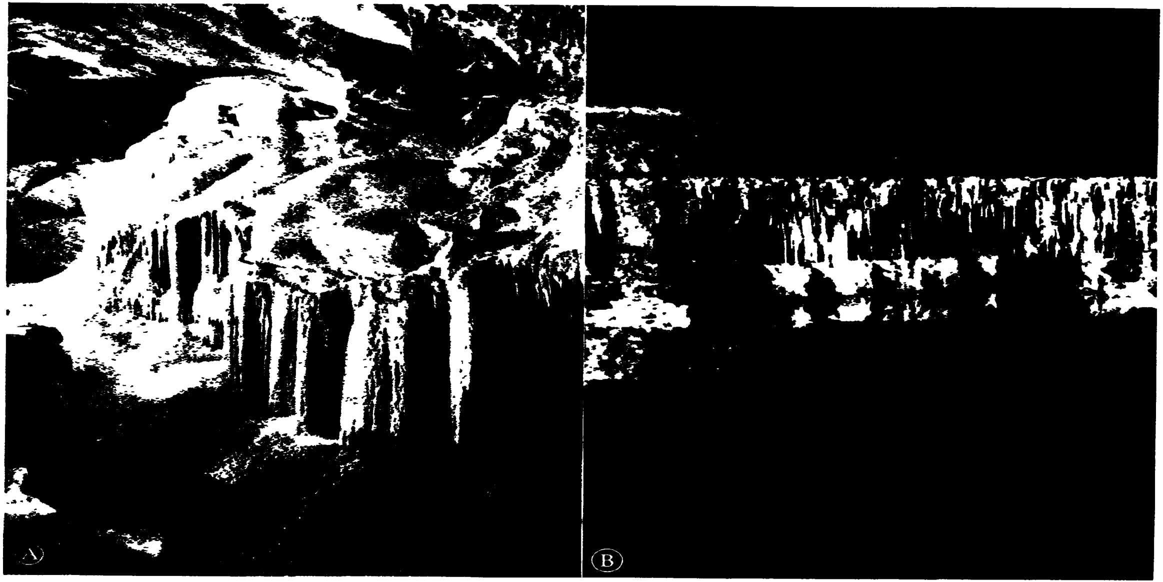


Plate 8. A, The Snowdrift, a mass of flowstone in Endless Caverns. The height of the Snowdrift is about 20 feet.
B, Diamond Lake with overhanging stalactites in Endless Caverns. Deposits of travertine around the base of the stalactites and bordering the lake have the appearance of miniature blocks of ice.

Plate 9. Curiously shaped stalactites and nodular growths in Endless Caverns. The Underground Cathedral, one of the prettiest chambers in the caverns, showing the wide variety and profusion of travertine deposits

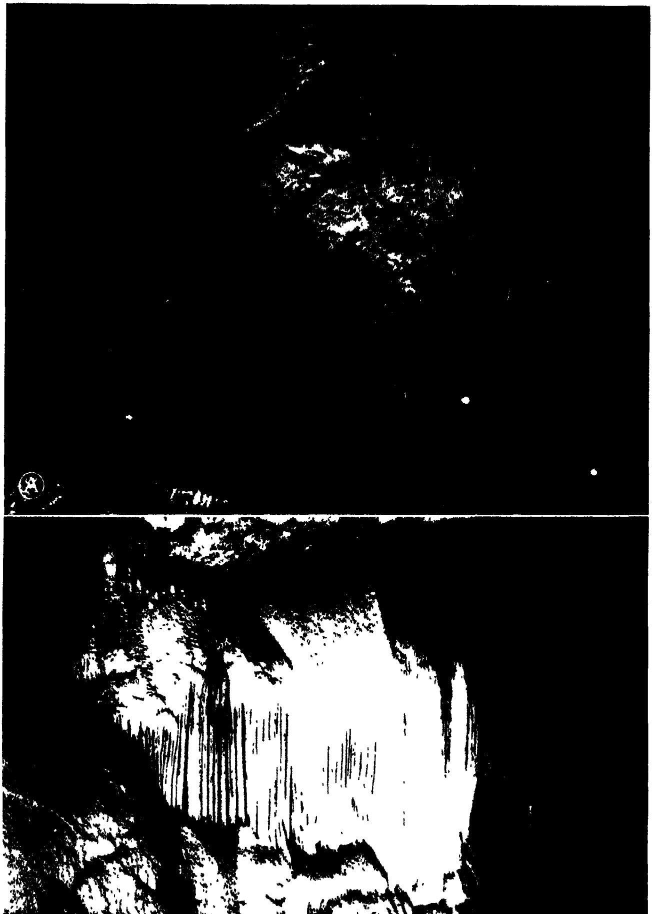


Plate 10. A, Capitol Dome and Indian tepees, huge stalagmites in Giant Caverns. (Courtesy Virginia State Chamber of Commerce.)
B, Great Falls, one of many massive flowstone deposits in Giant Caverns. (Photograph by Nunnally's, Inc.)

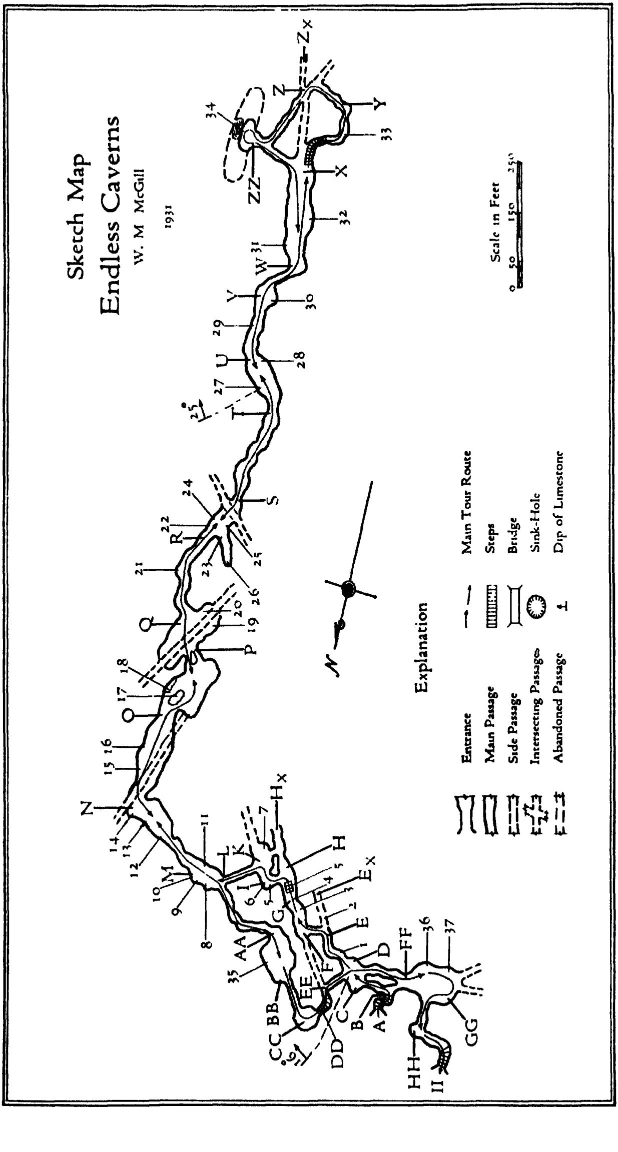


Figure 8.—Sketch map of Endless Caverns

Figure 8

EXPLANATION

A-B. Entrance Passage.
B-C. Rose Corridor.
C-D. Tree Grotto.
D-E. The Milky Way.
E-Ex. Rocky Gorge.
E-F. Narrow Passage.
F-G. The Mitten Room.
G-H-Hx. Grand Canyon.
H-I. Tunnel Pass.
I. Hindu Temple.
K. Skyland.
K-L. Straight and Narrow Passage.
L-M. Marine Corridor.
M-N. Alpine Pass.
N-O. Yosemite Valley.
O-P. The Ball Room.
P-Q. Solomon's Temple.
Q-R. Lovers Lane.
R-S. The Cloister.
S-T. Winding Passage.
T-U. Arctic Circle.
U-V. Boulder Canyon.
V-W. Unnamed Room.
W-X. Stephens Hall.
X-Y-Z. Circle Tour.
X-Z-Zx. Explorers Passage.
ZZ. Diamond Lake.
L-AA. Narrow Lane.
AA-BB. Oriental Palace.
CC-DD. Little Bronze Room.
EE-D-FF. The Long, Narrow Trail.
FF-GG. Underground Cathedral.
HH. Blue Room.
HH-II. Exit Passage.

1. Ceiling studded with milk-white stalactites.
2. Rock-and flowstone-filled passage.
3. Giant Mitten.
4. Etched limestone pendants.
5. Cup-topped stalagmites.
6. Cave Menagerie.
7. Fallen limestone blocks.
8. Lily Pads.
9. The Angel's Wing.
10. Fan-shaped, ribbon corrugations.
11. Undercut banks.
12. Chattahoochee Falls.
13. Sunset Falls.
14. Neptune's Throne.
15. Abandoned channels in ceiling.
16. Cobblestone Ceiling.
17. Giant Rock.
18. Weeping Willow Falls.
19. Suspension Bridge.
20. Double (Twin) Column.
21. The Portal.
22. Giant Shield.
23. Frost-coated stalagmites.
24. Fountain of Youth.
25. Helictites.
26. Bear's Den.
27. The Snowdrift.
28. Gypsy Tent.
29. The Frozen Cascade.
30. Hawaiian Village.
31. Sheet draperies.
32. Shields.
33. Land of Midnight Sun.
34. The Old Ice Pond.
35. Nodular, rounded concretions.
36. Variety and profusion of stalactites, stalagmites and columns.
37. Enlargements on stalactites.

ants of natural rock 2 to 6 feet long hang from the ceiling and the walls are picturesquely coated with tinted deposits of flowstone. Descending the Giant's Stairway, about midway of this corridor, one reaches the lower or second level and, turning abruptly to the left, passes through a short tunnel-like passage about 20 feet long to enter the Hindu Temple.

The Hindu Temple is a circular room about 30 feet across and about 8 feet high containing a profusion of stalactite and stalagmite formations resembling idols. Here are found cup-topped stalagmites similar to those in the Mitten Room (Pl. 39B).

To the right is Skyland, so named from the attractive bluish cast of the limestone ceiling, and considered by many visitors to be one of the prettiest rooms in the caverns. The floor is in places largely hidden by masses of fallen limestone blocks, some obscured under blanket deposits of flowstone from which rise clusters of stalagmites and frosty appearing columns.

Opposite Skyland one ascends a few feet to enter the Straight and Narrow Passage leading northeast about 100 feet to the Marine Corridor, one of the show-spots of the caverns. Here occur some of the most interesting features to be found in the caverns of Virginia. The Angel's Wing (Pl. 35A) is an impressive example of an artistically etched ceiling. The picturesque ruffled lily pads or basin-rim corrugations on the floor (Pl. 45B) are precipitations of calcium carbonate around the margins of pools of acidulated water collected in depressions in the floor. The most striking feature, from which the corridor gets its name, is a fan-shaped mass of ribbon-like corrugations radiating from a point along the left wall as if in motion across the floor (Pl. 46A). Several rounded or almond-shaped projections of the original limestone protrude from the ceiling in this and the next two rooms. The alignment of stalactites along joints in the ceiling is well shown in portions of the Marine Corridor

and in the Hindu Temple and Skyland. Undercut banks are also to be noted along the walls.

Continuing southeastward through a corridor partially obstructed by fallen blocks, one passes Chattahoochee Falls, the Theatre Curtain and Sunset Falls, picturesque flowstone deposits along the Alpine Pass and enters Neptune's Throne. The outstanding feature of this room is a circular channel in the ceiling carved out of the bedrock, in part, perhaps, by swirling acidulated water (Pl. 35A). Here also is found a very pretty group of stalactite-drapery formations.

To the right is Yosemite Valley, a corridor about 120 feet long and from 25 to 50 feet wide which extends in a general north-south direction. In this corridor is shown remarkably well the influence of stream erosion in the excavation of underground channels. Curiously shaped eroded and etched pendants from 1 to 3 feet or more in length project from the ceiling, which also contains several relatively deep-cut furrow-like channels. Near Neptune's Throne, an etched portion of the ceiling has the appearance of a street paved with cobblestones.

Through a restricted passage at the end of Yosemite Valley one enters the Ball Room, one of the larger rooms of the caverns. Near the center a gigantic suspended rock, measuring 90 feet in circumference and estimated to weigh between 200 and 300 tons, projects from the ceiling to within a few feet of the floor. From other parts of the ceiling hang several weird, toothlike and handlike pendants of eroded limestone. To the right of the suspended rock a bench about 3 feet high and 2 feet wide extends along the wall for about 5 feet. Weeping Willow Falls, a muddy-appearing, brown-tinted mass of flowstone reaches from a joint near the ceiling to the floor along a considerable part of the left wall. The original floor is covered with a hard-packed filling of transported clay deposited by the vanished underground waters.

A narrow, rock-filled passage leads into Solomon's Temple, an oval room about 80 feet across with a ceiling in places 25 feet high. Extending across it in a general northeasterly direction along the strike of the limestone are two connecting or feeder channel rifts from which hang tiers of flowstone draperies, smaller in size but resembling in appearance the rock-fish draperies noted in some of the other caverns. Massive deposits of flowstone bank the walls beneath the intersecting channels. In places, undercut banks and meandering abandoned channels occur along the walls. To the right of the path near the end of this room one looks over a protecting rock wall through a vertical chasm-like rift and sees the flowing waters of a stream which now occupies a channel some 90 feet below the floor. The passage over this shaftlike opening is called the Suspension Bridge. The Double Column, a graceful, fluted twin column, extends from an upper abandoned channel to a terrace-like mass of flowstone along the wall just beyond the Suspension Bridge. The cross channels, the massive deposits of flowstone, and the Double Column are shown in Plate 7A.

Following a narrow, circuitous passage, known as Lovers Lane, about 150 feet, one passes through the Portal, a natural arched gateway, to enter the Cloister. A large shield broken from the ceiling and suspended above the floor by stalactites, which project spearlike from it, guards the entrance. A short distance beyond occurs an attractive group of stalactites which appear to be coated with frost (Pl. 7B). Here is also the Fountain of Youth, a small, cup-shaped stalagmite into which falls an almost constant drip of water from a growing stalactite above. Numerous other columns and stalagmitic formations of much grace and beauty, among them Mount Vesuvius, occur here. On the right of the entrance a narrow side channel, the Bear's Den, extends northwestward

about 50 feet. Several hairlike helictites may be seen projecting from slender stalactites near the Fountain of Youth.

Following a winding passage filled with stalactites and stalagmites for about 140 feet, the Arctic Circle is reached. Just inside this room is the Snowdrift, one of the most beautiful formations in the caverns (Pl. 8A). It is a massive deposit of white flowstone which has accumulated beneath an ancient feeder channel that broke into the main passage high up on the wall. It has the appearance of a petrified cascade, with steeply terraced banks of spray occurring at the base of the falls. To the left of and beyond the Snowdrift, part of an abandoned circuitous channel eroded in the ceiling is visible.

At the end of the Arctic Circle is the Gypsy Tent formed by the intergrowth of three stalactite-adorned shields. Near here occurs also the Frozen Cascade, another realistic snow-white deposit of flowstone. Turning to the right the path leads almost south for some 95 feet through Boulder Canyon. A group of contrasting stalactitic, stalagmitic and drapery formations in a small side room at the end of Boulder Canyon is known as the Hawaiian Village.

The route now turns to the right and continues through the Unnamed Room, adorned with sheetlike and blanket-like flowstone and drapery formations and a hanging shield, into Stephens Hall, one of the largest as well as the last room in the main developed portion. Eroded channels occur in the ceiling, which here contains an interesting display of small stalactitic growths, in rows along the joints. Several baconstrip draperies and examples of broken sheet and shield forms are found here. Near the rear a large stalagmite and a graceful tapering overhanging stalactite form a natural stair newell post. To the right of this, one ascends by a winding path to Circle Passage, a circuitous passage about 300 feet long leading through the Land of the Midnight Sun.

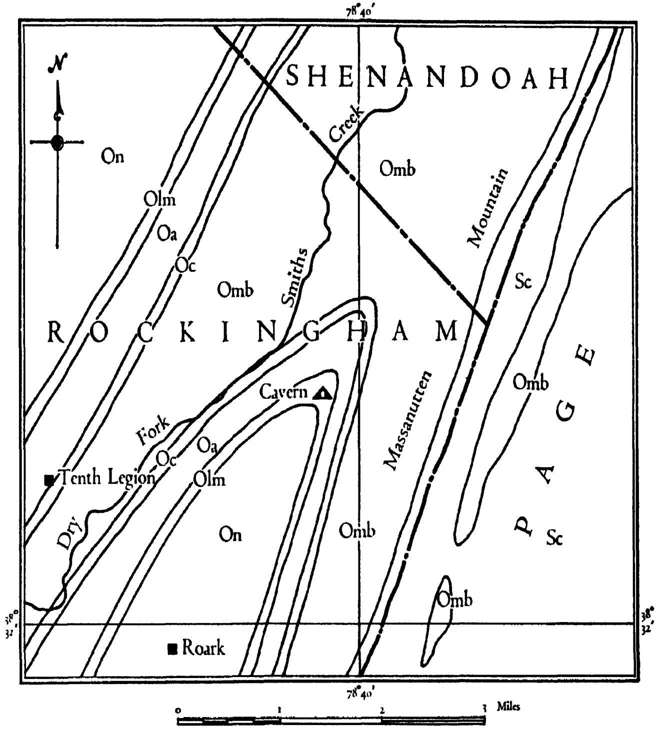


Figure 9.—Geologic sketch map of the environs of Endless Caverns. (By Charles Butts.) On, Nittany dolomite; Olm, Stones River (Mosheim and Lenoir) limestones; Oa, Athens formation; Oc, Chambersburg formation; Omb, Martinsburg formation; Sc, Clinch sandstone, Clinton group and younger formations.

At the south end of Stephens Hall, a narrow passage extends into the limestone, crosses the circuitous Circle Passage and leads to the Bottomless Pit, by which the explorers' party gained access to the stream-occupied channels 95 feet below. The route from the Circle Passage to the lower regions is known as the Explorers' Path.

At the intersection of these two passages one turns right and descends a few steps to be confronted with one of the most dazzling scenes in the caverns. At the base of the steps is a small crescent-shaped alcove about 25 feet wide and excavated to a depth of about 7 feet beneath the ceiling. Here, on either side and back of the crescent chamber, extends a shallow, nearly horizontal slit about 2 feet high and about 4 feet above the floor of the excavated chamber. From this vantage point one sees on three sides veritable fairylands of tiny, graceful stalactites and stalagmites such as only Nature can create. Beyond the crescent alcove is Diamond Lake, a shallow, crystal-clear lake about 10 feet wide. From the ceiling, which is here only about 18 inches above the lake, thousands of slender, delicate stalactites project into the water (Plate 8B). Groups of feather-like rosettes or miniature crystals of calcite, scintillating like diamonds, have formed around the base of the stalactites just above the surface of the lake. Other similar crystalline deposits occur around the margin of the lake just above the water level.

Reluctantly leaving Diamond Lake and returning to Stephens Hall, one retraces the main route to the Marine Corridor. Just beyond the passage by which one entered this room from Skyland, a narrow, winding corridor leads northwestward about 125 feet into the Bronze Room, also called the Oriental Palace. Here are found an engaging array of bronze-tinted stalactites, stalagmites, columns and stalactite-draped shields, many resembling animal or human shapes. On the floor of one of the passages occur numerous basin-rim or lily-pad corrugations sim-

ilar to those in the Marine Corridor. Of especial interest here is a deposit of concretionary forms about the size of marbles or walnuts embedded in the floor of a side passage. From the Bronze Room a narrow circuitous passage leads through the Little Bronze Room, up a flight of steps, across an abandoned channel which extends northwestward from the Mitten Room, past the Tree Grotto into one of the most beautiful chambers in Endless Caverns, the Underground Cathedral, sometimes called, with equal propriety, the Hall of Ten Thousand Stalactites. It is literally filled with a dazzling profusion of stalactites, stalagmites and columns of variable size, shape and color. The ceiling is one of the most richly decorated in the caverns (Pl. 9). On some of the many varieties of stalactites may be noted curious bulbous enlargements resembling pears, oranges, or similar shapes.

At the northwest end of the chamber two side channels, studded with groups of delicate stalactites and stalagmites, extend for considerable distances into the limestone. Leaving the Oriental Palace by a short, winding passage, one reaches the Blue Room from which the exit passage ascends to the floor of the rock lodge.

The elevation of the entrance is about 1,150 feet. The first passage, Rose Corridor, on the first or upper level, has an elevation of about 1,125 feet and Diamond Lake, the lowest point in the developed part of the caverns, is about 1,080 feet above sea-level. The floor of the Marine Corridor varies in elevation from about 1,110 feet at its northwest end to about 1,090 feet at its southeast end. The elevation of the floor of the longer section of the lower developed level varies from 1,090 at the low points to 1,110 feet in places where accumulations of transported and deposited material cover the original channel floor.

Giant Caverns

A short distance south of Narrows in western Giles County, Wolf

Creek Mountain rises to a prominent height and extends southwestward into Bland County. From the high school in Narrows, a winding sand-clay road gradually ascends the northeast slope of a prominent short spur ridge near the northeast end of Wolf Creek Mountain, to the entrance of Giant Caverns, about three-fourths of a mile southwest of the town (Fig. 3). These caverns are in the area shown on the Peterstown topographic map.

Giant Caverns are between Wolf Creek on the northwest and Mill Creek, a tributary to Wolf Creek, on the northeast. The entrance is about 1,960 feet above sea-level or about 250 feet above Narrows. The caverns consist of a series of large chambers and connecting corridors of variable dimensions, excavated along the northeast strike of the limestone. The developed portions are chiefly on two well-defined levels (Fig. 10). A series of high-vaulted large rooms occurs on the main (lower) level, roughly, some 70 feet below the entrance, and a continuous series of smaller corridors has been excavated on levels about 35 and 45 feet, respectively, above the floor of the lower chambers. The upper corridors are slightly to the left (southeast) of the lower passages but conform to them in following the strike of the limestone. The higher passages are portions of the older or earlier stream channels excavated before the lower, larger passages were opened up. The caverns are in the Stones River limestone of Ordovician age (Fig. 11 and Table 3).

It is probable that channels at two different levels once existed through most of the caverns. Through the continued enlargement of the lower passages and the breaking down of the rock between the two levels, the upper channel in the central part of the caverns has been destroyed, resulting in the high ceilings of the larger, lower chambers. The remaining portion of the upper channel at its junction with Giant's Hall is lower than the present ceiling of Giant's Hall.

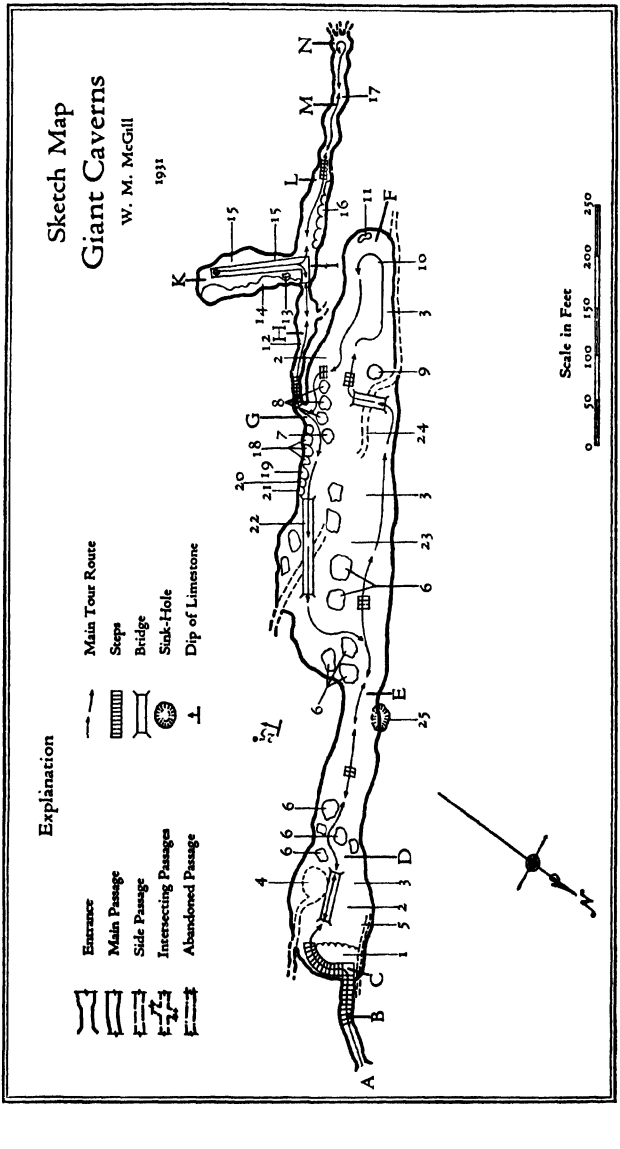


Figure 10.—Sketch map of Giant Caverns

Figure 10

EXPLANATION

A-B. Timbered Passage.
B-C. Entrance Stairway.
C-D. Reception Room.
D-E. The Library.
E-F. Giant's Hall.
G-H. The Gallery.
H-I. Robbers' Den.
I-K. Pie Crust Room.
I-L. Indian Pass.
L-M. Upper Passage.
M-N. Last Room.

1. Flowstone terrace.
2. Rows of stalactites along joints.
3. Stalactite- and drapery-adorned shield.
4. Mystery Lake.
5. Basin-rim corrugations.
6. Broken limestone blocks.
7. Capitol Dome.
8. Giant Tepees.
9. The Organ.
10. Radiating, ribbon corrugations.
11. The Bench.
12. The Japanese Gardens.
13. The Christmas Tree.
14. Niagara Falls.
15. Pie crust, basin-rim corrugations.
16. Indian Wigwams.
17. Reverberating and cobbled floor.
18. Giant Snowballs.
19. Elephant Rock.
20. Crystal Spring.
21. Great Falls.
22. The Bridge of Sighs.
23. The Beach.
24. Underground stream.
25. Original entry.

The large fragments of broken rock throughout the lower passage, particularly in the Reception Room and Giant's Hall, and the large amount of smaller fragments in the abandoned stream bed through these rooms, suggest further that the development of these spacious passages was due in considerable measure to erosion of limestone between the higher and lower levels.

The sloping corridor through which entry to the main caverns is made was doubtless a channel through which much surface water entered the lower portion of the caverns. This is evidenced by the massive flowstone terraces at the entry (northeast) end of the Reception Room. The elevation of the entry landing to the Reception Room is approximately the same as that of the upper channel at the southeast end of Giant's Hall. It is possible that the entry passage represents a portion of the higher partly destroyed channel at the far end of Giant's Hall. It is, however, more probable that the entry passage was excavated by surface waters seeping southwesterly along a joint leading into the Reception Hall after this room had been formed. It is thought that previously the waters which had formed the Reception Hall deserted this chamber, cutting through to a lower level along a prominent joint in the northeast corner of the Hall to the right (northeast) of the huge deposit of flowstone.

From the basement of the former Visitors' Lodge on a knoll of Wolf Creek Mountain, a steeply sloping timbered passage about 7 feet high and 8 to 10 feet wide extends southwest for 50 feet to a flight of steps which, bearing slightly to the right, leads to a stair landing at the entrance to the Reception Room, the first and lowest room in Giant Caverns. From the stair landing, which is about 40 feet below the surface entrance, the visitor is at once impressed with the size of this room so fittingly named. From this vantage point one may note the array of stalactites along joints

in the ceiling, a stalactite-adorned shield, terraced masses of flowstone along the entrance side of the room, and several large broken rocks near the right wall.

From the landing, steps lead to the left along the wall of the room to the floor of the Reception Hall, some 30 feet below, where a more impressive conception of the size of this chamber may be obtained. From the nearly vertical right wall to the steeply inclined left wall, this chamber measures 90 feet in width. Its length from the stair landing to the narrow passage beyond the bridge over Mystery Lake is approximately 100 feet. In the center the domed ceiling is some 35 feet above the floor. Along the right wall may be seen a shallow abandoned channel winding amid fragments of broken rock and along which occur several rill-like, basin-rim corrugations. Along the base of the left wall, and near the foot of the steps, is a small inclined side channel through which the waters from Mystery Lake, the stream which excavated the Reception Hall, left this room to seek a channel at still lower depths.

Crossing Mystery Lake by a wooden footbridge, the path leads through a restricted passage between large broken rocks to the Library, with its artistically arched ceiling. It is a corridor some 165 feet long, 40 to 60 feet wide, and 18 to 20 feet high. Near the center the path ascends about 6 feet by steps, and a short distance beyond to the right is the old or original entrance. At this point, the surface is only some 40 feet above the ceiling.

Near the old entrance the Library narrows to about 25 feet. A short distance beyond, the path winds around a huge block of limestone and emerges suddenly into the Giant's Hall, the largest individual chamber in any of the known caverns of Virginia. It has a maximum width of 125 feet and its total length exceeds 450 feet. The ceiling is from 85 to 95 feet above the level of the old rock-filled stream channel which winds

in a northeasterly course through a portion of this Hall to disappear in a side channel in an alcove along the left wall 40 to 50 feet beyond the Rock Canyon Bridge.

Of special interest in Giant's Hall are the many large limestone slabs broken from the ceiling countless years ago, the great amount of fragmental material which now fills the old stream channel, the enormous flowstone terraces at the far end and similar but less extensive terraces to the right of the path along the right wall (Pl. 10A). Probably the most impressive features are the magnificent stalagmites shaped like cones and wigwams, 20 to 25 feet high and 15 to 20 feet in diameter, which tower above a high flowstone terrace near the ascent to the upper channel passages (Pl. 10A).

Opposite the huge stalagmites the path, which has been close to the right wall, turns abruptly to the left and crosses the old stream channel by a narrow bridge, beneath which gurgling waters are heard. A small stream of undetermined but probably small volume flows through a portion of Giant's Hall. It apparently enters this chamber through a side channel, a portion of which may be seen along the right wall beyond the bridge. Its course can be traced for 75 feet or more through the mass of fragmental material in the old stream bed.

At the rear (southwest) of Giant's Hall, beyond the bridge, the path leads up to the broad flowstone terrace which flanks this end of the large chamber. Passing the Organ and one or two large individual stalagmite formations, one reaches the end of the lower channel. On the right wall are a group of brownish draperies and two attractive shields. Through an ancient inclined vent one may see below to the right a part of the abandoned side channel which continues southwestward for some distance into the limestone.

Two objects of interest on this terrace, at the extreme end of

Plate 11. The Christmas Tree and Niagara Falls, realistic stalagmite and flowstone deposits in the Pie Crust Room, Giant Caverns. They seem to be thickly mantled with snow and ice. (Photograph by Nunnally's, Inc.)

Plate 12. A spectacular underground chasm in Grand Caverns. The Lindbergh Bridge, a huge rift showing channels at two levels above the main passage and tiers of "rockfish" draperies fringing the rifts and walls.

Plate 13. A, Broken shields and columns in Grand Caverns accumulated at the entrance to a large chamber. Secondary stalagmites occur on some of the blocks. The shields have a diameter of about 3 feet.
B, Oyster Shell shields in Grand Caverns. Note the development of the shields and small, slender stalactites along a bedding plane in the ceiling. The lower Oyster Shell measures 7 by 8 feet.

Plate 14. Cathedral Hall in Grand Caverns with a ceiling 60 feet high. Note the long, tapering stalactites, flowstone and drapery on the walls and the huge stalagmite in the background.

Giant's Hall, are an alcove bench and a series of concentric wavy travertine corrugations on the terrace floor. From this elevated platform, one may obtain another impressive view of Giant's Hall, the width of which at this end is about 60 feet.

From here the path leads to the left along the terrace to the opposite (left or southeast) side of the hall and after one ascends a few steps he finds himself behind the towering tepee-shaped or dome-shaped stalagmites. Directly in the rear of these huge forms the path clings to the left wall, along which a stairway some 16 feet high leads southwest to the upper channel. At the top of the stairway to the right is a large stalagmitic pillar covered with flowstone and to the left in a small cleft along the base of the wall are the beautiful Japanese Gardens. One next passes through the Robbers' Den, a weird alcove on the right, and by a short passage reaches the Pie Crust Room.

The Pie Crust Room is one of the most interesting and fascinating chambers in the caverns. It is about 110 feet long, 30 to 50 feet wide, and from 7 to 18 feet high. The entire floor is encrusted with wavelike "pie crust" corrugations of travertine as much as 10 inches in height. In the ceiling may be noted eroded abandoned channels and nests of rounded holes. Here occur Niagara Falls and the Christmas Tree, two striking examples of travertine formations (Pl. 11). Along the left wall is a series of billowy rolls, or fluted cascades of flowstone, deceptively fluid-looking to the eye, but like all the underground wonders, a solid mass of stone. This petrified cataract has been named Niagara Falls. At one end and in front of the cascades stands a beautiful tiered or step-growth stalagmite apparently covered with a mantle of scintillating snow crystals which has been appropriately named the Christmas Tree.

From this room the path leads through the picturesque Indian Pass, a corridor about 25 feet wide and 80 feet long, flanked on the

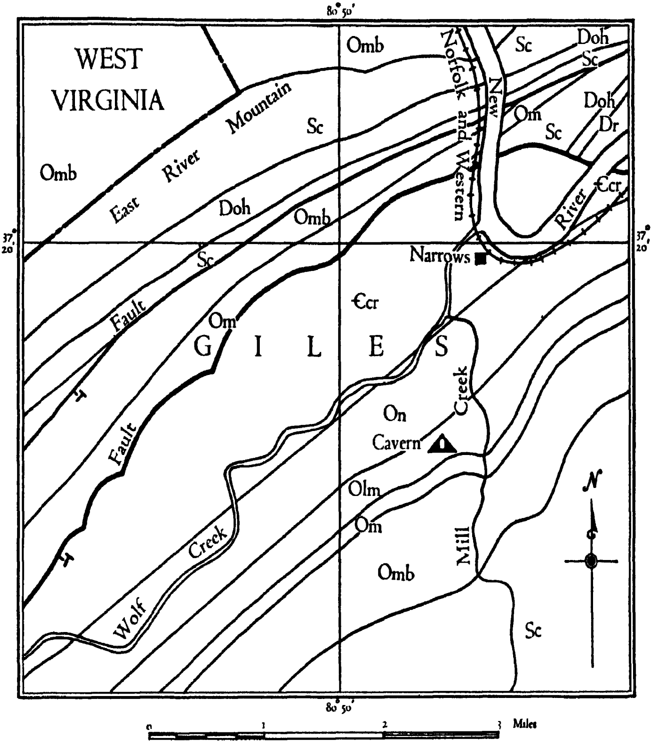


Figure 11.—Geologic sketch map of the environs of Giant Caverns. (By Charles Butts.) Ꞓcr, Copper Ridge dolomite; On, Nittany dolomite; Olm, Stones River (Mosheim and Lenoir) limestones; Om, Moccasin formation; Omb, Martinsburg formation; Sc, Clinch sandstone and Clinton group; Doh, Helderberg group and Oriskany sandstone; Dr, Romney shale.

right for most of its length by a row of beautifully tinted stalagmites and draperies which closely resemble a row of Indian tepees. The coloring of the travertine formations in this passage is beyond adequate description. Variegated shades of brown, gray, purple and orange blend here and there into fascinating silver-bronze tints. Portions of an ancient abandoned channel are well preserved in the ceiling.

At the rear of Indian Pass, steps lead upward about 10 feet to a relatively narrow circuitous passage which extends southwest some 85 to 90 feet, and ends suddenly in a small alcove into which several small, inclined, feeder passages lead from possible higher levels or from surface drainage channels. Several examples of etched remnants and projecting portions of the original limestone protrude from the ceiling and walls in this, the last passage. The floor here emits a hollow, reverberating sound at places when trod upon heavily, indicating a probable cavernous channel at a slight depth below.

Retracing one's way to the terrace at the foot of the stairway in Giant's Hall, one follows the path along the flowstone terrace fringing the southeast wall of Giant's Hall, past a picturesque group of stalagmitic snowballs and wigwams, through the Garden of the Gods to the Bridge of Sighs. Just before reaching the bridge, one passes on the right Crystal Spring, a picturesquely framed, eternally dripping fountain, and Elephant Rock, a realistic mastodon of stone. Here also is Great Falls, a large, sparkling white flowstone cascade of much beauty (Pl. 10 B).

Passing over the Bridge of Sighs, the visitor reaches the old, abandoned, sandy stream bed across which he wends his way through the fallen rocks to the entry path at the northwest end of Giant's Hall. From here he returns by the same route to the entrance on the northwest slope of Wolf Creek Mountain.

From the crest of the mountain near the entrance to the caverns may be had views of some of the most impressive scenery to be found in this picturesque Valley Ridges section of Virginia.

Grand Caverns

Grand Caverns are in northern Augusta County about 16 miles north of Waynesboro, via Route 809, and about 8 miles east of Mount Sidney on the Lee Highway (Route 11), via Route 812 (Fig. 3). They are three-fourths of a mile west of the village of Grottoes on the Norfolk and Western Railway. Discovered in 1804 by Bernard Weyer, these caverns were long known as Weyer's Cave. They were later named Grottoes of the Shenandoah and then renamed Grand Caverns. They are in an area shown on the Harrisonburg topographic map. These caverns and many of the interesting features found in them have been described by Porte Crayon (David Strother),[19] and Hovey.[20]

Cave Hill, in which the caverns have been excavated, is one of a series of rather narrow, elongate limestone hills which rise somewhat abruptly to heights of 150 to 250 feet above and a short distance west of the South Fork of Shenandoah River. It is a narrow, closely folded northeasterly trending anticline with steep dips to the southeast and northwest. The entrance to the caverns is on the east slope of Cave Hill at an elevation of about 1,210 feet, or approximately 85 feet above the river. A graveled hillside path leads to the entrance.

That part of Grand Caverns open to visitors consists of a series of long, relatively narrow corridors and several spacious rooms connected by narrow, short passages. Numerous connecting channels, intersecting and intermediate passages and side channels occur at intervals along the main tour. The main passages were excavated chiefly along the northeast trend or strike of the limestone. They are in two separate but nearly

parallel courses developed somewhat *en echelon,* on approximately the same level, about 350 feet apart and connected by a shorter passage excavated at right angles to the trend of the limestone. The east-west (cross) passage is on a lower level than the major strike channels and the elevation of the floor in several places in this part varies as much as 25 feet in comparatively short distances (Fig. 12).

The elevation of the floor at the entrance is approximately 1,210 feet and the floor beneath the Giant Oyster Shell formation in the Shell Room at the far end of the cavern is about 25 feet lower. It is claimed by the guides that the Shell Room is about 200 feet beneath the crest of Cave Hill.

The length of the main traversed passage from the entrance to the rear of the Shell Room is approximately 1,700 feet. The total tour of the developed passages and the larger alcoves and side rooms, such as the Bridal Chamber, the Lily Room, the Armory and Bryce's Canyon, is about 3,800 feet.

The caverns are in the Conococheague limestone of late Cambrian or Ozarkian age (Fig. 13 and Table 3).

Abandoned passages adorned with travertine are known to occur at two different levels above the present tour level, and one is known at an estimated depth of 85 feet below the entrance level. Probably one of the most spectacular sights in the entire cavern is to be had in Jackson's Hall. Looking upward through chasmlike rifts one sees portions of abandoned passages adorned with travertine at two distinct levels (Pl. 12). The floor of the first is about 45 feet and that of the second some 80 feet above the floor of Jackson's Hall. The ceiling of the upper level, plainly visible from below and profusely decorated with stalactites, was found by the present owners to be 95 feet above the floor in Jackson's Hall. The drapery-encrusted gorge between the first and second

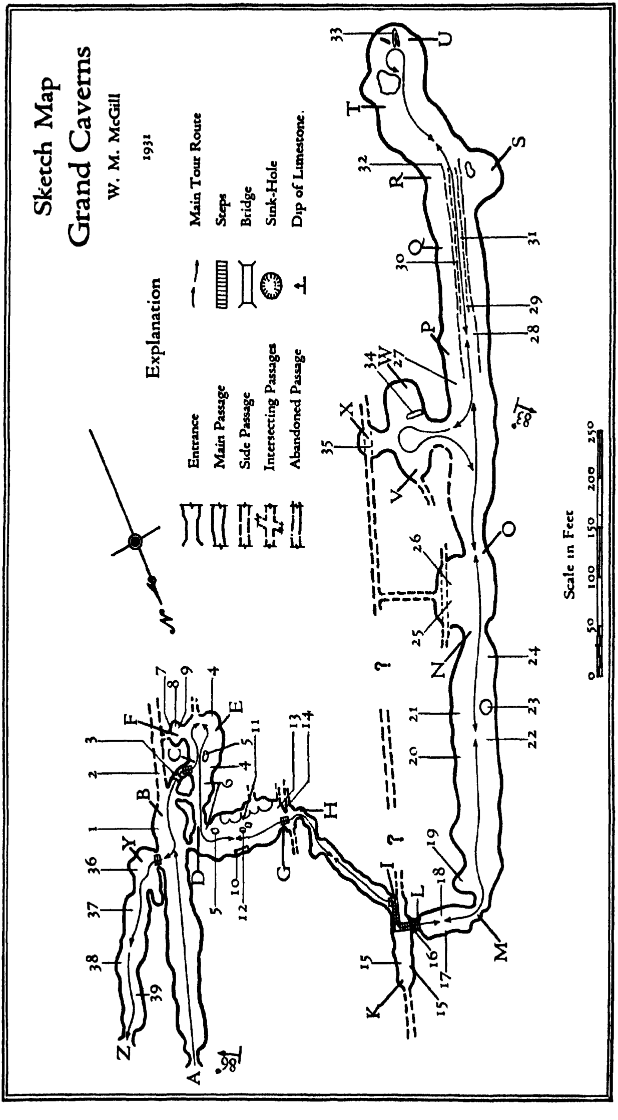


Figure 12.—Sketch map of Grand Caverns

Figure 12

EXPLANATION

A-B. Roxy's Cathedral.
B-C. Natural Bridge Pass.
C-D-E. The Persian Palace.
F. The Armory.
D-G. The Ball Room.
G-H. The Alcove.
H-I. Lovers' Lane.
I-K. Jacob's Ladder.
L-M. Senate Gallery.
M-N. Cathedral Hall.
N-O. Lily Room.
O-P. Jefferson's Hall.
P-Q. Grand Canyon.
Q-R. Jackson's Hall.
S. Wonderland.
R-T. Sunset Park.
T-U. Shell Room.
V-W. Bridal Chamber.
X. Drapery Alcove.
Y-Z. Bryce's Canyon.
Z. Exit.

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1. The Zoölogical Garden.
2. Rocky Way.
3. Natural Bridge.
4. Flowstone terraces and deposits.
5. Broken travertine forms.
6. Inclined stalactite- and drapery-adorned shields.
7. Ajax's Shield.
8. The Leaning Tower.
9. Crystal Cascade.
10. Flowstone- and drapery-fringed bench.
11. Undercut banks.
12. Sentinel stalagmites.
13. Wavelike, streamer corrugations.
14. Sheet-rock wall.
15. The "water line" (narrow band of travertine).
16. Natural Tunnel.
17. Shelves and ledges.
18. Suspended balcony.
19. Stage alcove.
20. Horseshoe Falls.
21. Massive streamer draperies.
22. Cup- or saucer-top stalagmite.
23. Giant stalagmite.
24. Terraced, step-growth stalagmites.
25. Grotto of the Lily.
26. Calla Lilies.
27. Statue of Thomas Jefferson.
28. Lindbergh Bridge.
29. Drapery-fringed chasms.
30. Rockfish draperies.
31. Peanut Gallery.
32. Statue of "Stonewall" Jackson.
33. Oyster Shells.
34. The Bridal Veil.
35. Draperies.
36. Palace of Fine Arts.
37. Profuse and varied array of stalactites.
38. Stalagmites apparently coated with pebbles.
39. Terraced and fluted columns.

levels has been named Lindbergh Bridge. The higher channel with its fringing tiers of stalactites is called by the guides the Peanut Gallery.

Among the more notable features found in Grand Caverns are the massive, driftlike, flowstone-coated deposits which occur at intervals. They are most prominently developed at the intersection of cross channels or at the junction of tributary stream courses with the main passage. The clogging of parts of the main channel, or the outlets of large rooms, by deposits of transported debris and broken travertine is well illustrated in certain of the chambers, particularly in the Persian Palace, Ball Room, and the Senate Chamber. Benches, shelves and undercut banks also occur in these rooms (Pls. 32 and 36A).

Probably the most characteristic and most interesting travertine formations are the "shields." These formations, which are greatly admired, are found in some of the other caverns of Virginia, but nowhere in such variety and profusion as in Grand Caverns. Broken shields adorned with stalactites appear in many places lodged amid groups of columns or against projections on the wall in the larger rooms (Pl. 13A). Several attractive scarf-draped or blanket-draped shields project from the side walls, of which the beautiful Bridal Veil (Pl. 16) is a magnificent example. It is a giant shield, some 10 to 12 feet in diameter, hanging disc-like from the side wall about 35 feet above the floor. A thin sparkling white veil-like sheet of drapery hangs from the shield to within a few feet of the floor. The Oyster Shells (Pl. 13B), in the Shell Room at the far end of the caverns, are other striking examples of these shields. Their probable origin is discussed under "Travertine Deposits" in Chapter V.

One passes through the entry gate directly into Roxy's Cathedral, a picturesque avenue varying in width from 30 to 50 feet and having an average height of 30 feet. It extends slightly west of south for about 250 feet. The Zoological Gardens, a spectacular "show spot," is a min-

Plate 15. Grotto of the Lily in Grand Caverns. Shows the growth of a shield along steeply inclined bedding plane in the ceiling and lily-shaped twin shields beneath an abandoned feeder channel.

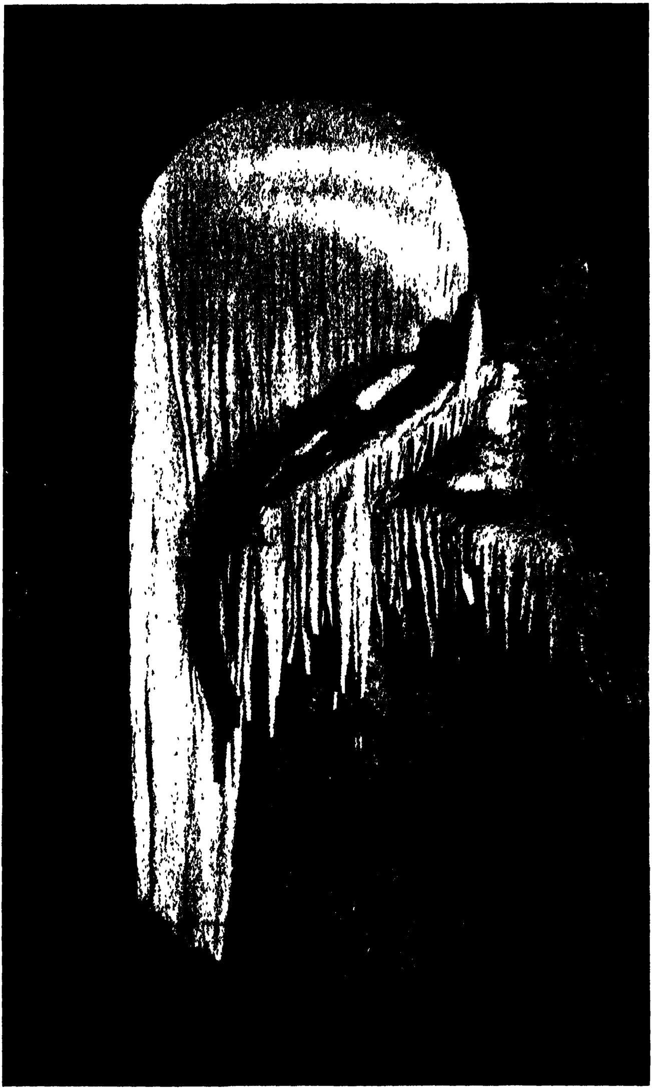

Plate 16. The Bridal Veil in Grand Caverns. This magnificent drapery-adorned shield projects from the wall of the Bridal Chamber,

iature menagerie in stone at the south end of Roxy's Cathedral. This passage was excavated along the strike of the limestone, as may be noted by the numerous exposures of the nearly vertical beds and bedding planes. Several side passages and inclined feeder-channels occur along this corridor. At the south end of the Zoölogical Gardens an abandoned rock-filled passage extends some distance into the native limestone. Here one turns to the right and passes under Natural Bridge and through a narrow passage about 40 feet long to descend about 4 feet by concrete steps into the Persian Palace.

The Persian Palace contains several striking features and is considered by many to be one of the most attractive rooms in the caverns. It is about 100 feet long and from 60 to 80 feet wide. Its floor is some 6 feet lower than that of Roxy's Cathedral and its ceiling is 15 to 25 feet above the floor. In the center is a massive group of intergrown columns and stalagmites encircled at the base by banks of flowstone. Terraces of flowstone flank the lower part of the side walls, in places reaching nearly to the ceiling. A large deposit of flowstone, resembling a solidified waterfall, extends across the southwest end. Above it a narrow feeder channel, through which it is probable that much of the flowstone came, penetrates the limestone in a southwest direction nearly parallel to the abandoned channel from the Zoological Gardens. The ceiling is thickly studded with stalactites of variable shape and length. Three interesting examples of shields occur in this room, one being along an exposed bedding plane of the limestone and two suspended in inclined positions from the partly fractured roof.

At the south end of the Persian Palace, to the left, is the Armory, an interesting alcove about 25 feet deep and about 35 feet wide. Here hangs Ajax's shield from which project several saber-shaped stalactites. Other weapon-like groups of travertine formations project from the ceiling

and walls. Near the right wall rises a graceful stalagmite which has been named the Leaning Tower, because of its resemblance to the Leaning Tower of Pisa. Above Crystal Cascade, a terraced flowstone deposit in the rear of the alcove, a small inclined channel extends to the abandoned channel from Roxy's Cathedral. The amount of flowstone in the Armory indicates that a considerable volume of water entered the Persian Palace through this inclined channel.

From the Persian Palace one enters the Ball Room, 100 feet long, 30 to 50 feet wide and 20 feet high. It is a conspicuous example of a large chamber excavated along a prominent joint across the strike of the limestone. The variations in the color of the travertine formations and of the ceiling in the Ball Room are particularly attractive. The growth of stalactites and the formation of shields along nearly vertical bedding planes in the ceiling are well shown both here and in the Grotto of the Lily (Pls. 15 and 32). Along the right wall of this room near the entrance and about 3 feet above the floor, there is a small bench from which rise several small stalagmites (Pl. 36A). Of particular interest are the sentinel stalagmites in the center of the room, the picturesque shields clinging to the ceiling, and the travertine curtain which forms a natural "sheet-rock wall" between the Ball Room and the winding passage of Lovers' Lane beyond.

All of the left wall of the Ball Room is concealed by massive banked deposits of flowstone which in places have been undercut, exposing broken limestone slabs beneath. At the end of the Ball Room, near the sheet-rock wall, several parallel wavelike bacon-strip streamers of travertine occur in the ceiling above the huge deposit of flowstone. They range in length from 4 to 18 inches and are from one-half to three-quarters of an inch thick. They are thought to have been formed as small sheet-like veins along the bedding planes in the

ceiling and to have been exposed by the later solution of the limestone between them.

Passing through a narrow door in the sheet-rock wall, one ascends about 3 feet by concrete steps to the Alcove, the entry chamber to Lovers' Lane. A well-defined inclined strike channel cuts across the main passage in this room and is largely responsible for its circular shape.

Lovers' Lane, a narrow circuitous passage, extends from the Alcove in a northwesterly direction for about 160 feet. A sudden turn to the right brings one to Jacob's Ladder, a deeply cut strike channel about 25 feet wide and 100 feet long, which connects Lovers' Lane with the Senate Chamber on a level about 25 feet lower. It is excavated along the strike of the limestone nearly transverse to the Senate Chamber. It has a height of about 30 feet, its floor being about 21 feet below and its ceiling about 9 feet above the floor of Lovers' Lane. A narrow concrete stairway leads from Lovers' Lane to the floor of Jacob's Ladder, where one turns sharply to the left to pass northwestward again through a small natural limestone arch into the Senate Chamber.

The nearly vertical attitude of the limestone through Jacob's Ladder is clearly shown by exposed parts of the bedding planes in the ceiling. A narrow band of travertine is exposed around the walls of Jacob's Ladder about 5 feet below the floor of Lovers' Lane. This black band marks the original floor level of the Lovers' Lane passage through which the waters excavated the deep Jacob's Ladder passage, opening a lower channel along the bedding plane of the limestone to the surface.

There is a small opening on the lower slope of Cave Hill, about 250 feet northeast of the entrance to Grand Caverns and a few feet above the road from Grottoes to Grand Caverns, which is about 50 feet below the floor of Jacob's Ladder and is almost in strike with it. It is thought

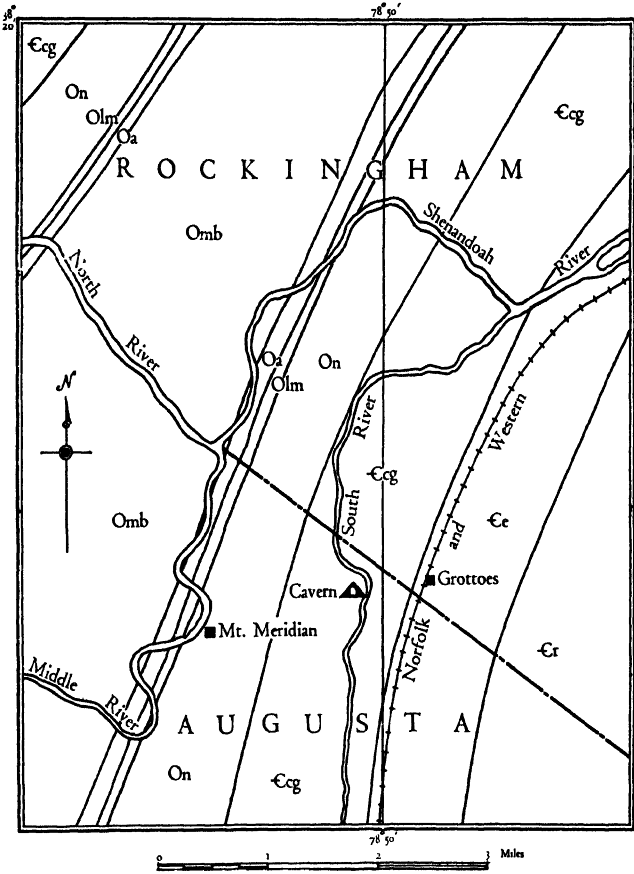

Figure 13.—Geologic sketch map of the environs of Grand Caverns. (By Charles Butts.) €r, Rome ("Watauga") formation; €e, Elbrook limestone; €cg, Conococheague limestone; On, Nittany dolomite; Olm, Stones River (Mosheim and Lenoir) limestones; Oa, Athens formation; Omb, Martinsburg formation.

that this opening is the surface outlet of the Jacob's Ladder channel and is the exit through which much of the water which probably for a time filled Lovers' Lane, the Senate Gallery, and possibly also the Persian Palace, the Ball Room, and Cathedral Hall, reached the surface. It is also thought that much of the transported fragmental material noted in parts of these chambers was deposited by the water which suddenly deserted them to seek lower courses through Jacob's Ladder and other similar steeply inclined drainage channels along the strike of the limestone.

The Senate Chamber unites Jacob's Ladder and the second long series of rooms and passages excavated along the strike of the limestone. It is about 65 feet long, 30 to 45 feet wide and 20 to 30 feet high. Interesting features here are an undercut shelf, a suspended balcony and a large amount of silt and stream-deposited material covered with flowstone. The tour passage through this chamber has been cut through deposited material 5 feet deep.

From the Senate Chamber, a narrow winding passage about 15 feet long leads to Cathedral Hall, the longest and one of the most interesting chambers in the caverns (Pl. 14). It is some 280 feet long, 40 to 60 feet wide, and 40 feet high. It contains several very pretty shields, a variety of attractive stalactites, fluted draperies of great beauty, graceful columns and much flowstone, of which Horseshoe Falls is a very striking and colorful example. In a small alcove at the north end of Cathedral Hall is found a most pleasing display of travertine deposits, particularly shields and stalactites grouped like a stage setting. The ceiling of Cathedral Hall is beautifully etched and in places artistically corrugated.

The Lily Room, an enlarged room at the end of Cathedral Hall, is another interesting chamber. In the small alcove opening from this chamber, which has been appropriately named the Grotto of the Lily,

are found an inclined shield and two beautiful sparkling stone calla lilies. Here also may be noted an inclined channel from above and two small nearly horizontal feeder channels parallel to the main passage. The steeply inclined bedding planes of the limestone are well shown in the ceiling of this attractive little grotto (Pl. 15).

Beyond Cathedral Hall are Jefferson's Hall, distinguished by a realistic statue of Thomas Jefferson, and the magnificent Grand Canyon which contains the Lindbergh Bridge and Peanut Gallery chasms already described (Pl. 12). From Jackson's Hall the main tour leads through the realistic Red Sunset Park, with its colorful masses of flowstone, to the Shell Room, the last room in the caverns.

No other formations in Grand Caverns are as much admired or more justly praised than the two immense Oyster Shells which give the Shell Room its name (Pl. 13B). The upper one is 6½ feet wide by 11 feet long and the lower one is 7 by 8 feet. Graceful, slender stalactites are thickly aligned along the steeply inclined bedding planes in the ceiling, and the Oyster Shells are artistically fringed with similar dainty forms. A stalactite-studded shield, long ago broken from the ceiling, has embedded itself in the cavern floor near the Oyster Shells.

Leaving the Shell Room and returning to Jefferson's Hall, the visitor enters to the right one of the most attractive side rooms in the caverns, the Bridal Chamber. It is about 100 feet long and 50 feet wide. Here is found the resplendent Bridal Veil (Pl. 16), a drapery-shrouded shield of matchless beauty, already described in some detail. Of interest here are the masses of broken rock with which the south end of the room is filled, and the higher channel which may be partly seen beyond the Bridal Veil above the mass of broken flowstone-covered material. A statuesque sentinel stalagmite rises about 5 feet above a shelf-like portion of the old floor of the upper passage. The Drapery Alcove, a

secluded nook, contains several attractive drapery and flowstone formations. Through the upper part of this small room, a tributary feeder channel extends along the strike of the limestone almost in line with the cross channel through Jacob's Ladder. It is possible that a continuous channel exists between these two, which may extend through the limestone nearly the full length of the developed passages.

From the Bridal Chamber one retraces the main passage to a point near the southwest end of Roxy's Cathedral. Here a few concrete steps lead downward to the right through a picturesque alcove into Bryce's Canyon, a relatively new addition to the cavern tour. This is a very interesting passage, about 200 feet long, 8 to 18 feet wide and 8 to 20 feet high. It is one of the "show spots" of the caverns and contains a varied and interesting collection of attractive stalactites, stalagmites and columns. The level of this chamber is in places nearly 10 feet below the level of Roxy's Cathedral. Bryce's Canyon is the exit route of the cavern tour and leads to an outlet about 40 feet southwest of the entrance gate.

Luray Caverns

The beautiful Caverns of Luray are within 200 yards of the Lee Highway (Route 211), 1 mile west of Luray and 14 miles east of New Market (Fig. 3). The entrance is on the east slope of Cave Hill in picturesque Page Valley, about midway between Massanutten Mountain on the west and the Blue Ridge on the east. A tree-bordered, hard-surfaced road leads north from Route 211 to Luray Lodge and the entrance. These caverns are in the area shown on the old Luray and the new Stony Man topographic maps.

These caverns are among the largest developed caverns in Virginia and are considered by many to be among the world's subterranean wonders. They have been continually open to the public since 1878, when

they were discovered, and have been described by Ammen,[21] Hovey,[22] and Lusk.[23] They contain an amazing variety and profusion, in form and color, of travertine formations and afford a great number of outstanding and impressive "show spots" and features of scientific interest.

The association of sinks and sink-holes with caverns and their excavation are well shown by the number of such features in the vicinity of Luray Caverns. There is an interesting circular sink, about 1,000 feet across at the surface, immediately in front of the cavern entrance. It is bordered by a row of trees and encircled by the entrance roadway. Another sink of considerable size occurs at the rear of the lodge. The entrance to Ruffner's Cave, known before the discovery of Luray Caverns, is on the west side of Cave Hill.

The entrance to the caverns is by a concrete stairway from the main lobby of the attractive gray stone lodge. The elevation of the entrance is 972 feet, about 100 feet higher than Hawksbill Creek, which flows northward about 1 mile to the east and discharges into the South Fork of the Shenandoah about 3½ miles north of Luray. The crest of Cave Hill rises about 230 feet above the entrance to an elevation of about 1,200 feet. The floor of Entrance Avenue, at the foot of the stairway, is about 933 feet and that of the Amphitheatre about 914 feet, above sea-level. The lowest point, at the entrance to the Palace of Splendors, is about 902 feet above sea-level.

Luray Caverns comprise a complicated system of spacious rooms, ranging in height from 30 to 90 feet, connected by natural branching, intersecting and looped passages excavated on four different levels. A map of the known chambers and side channels resembles a giant spider web (Fig. 14). A close examination of this sketch map shows a rather definite northeast-southwest alignment of the longer passages. More

Plate 17. The Cathedral in Luray Caverns. Here occurs an impressive array of long, folded blanket draperies, giant, fluted step-growth stalagmites and terraced columns. (Copyrighted by Luray Caverns Corp.)

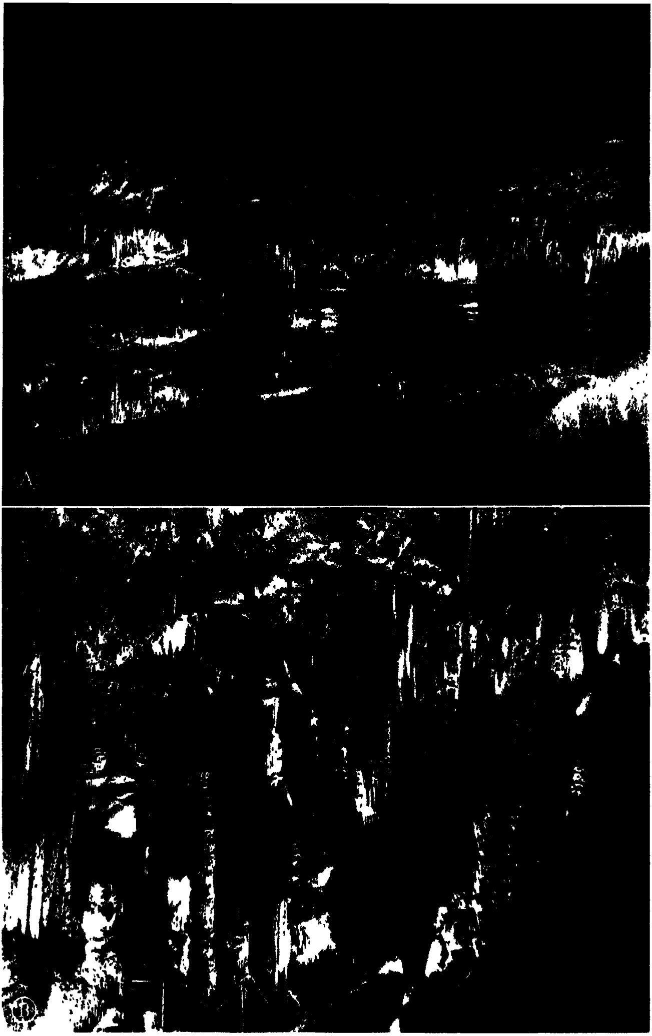

Plate 18. A, Dream Lake in Luray Caverns. Note the reflection of the stalactites above it. (Copyrighted by Luray Caverns Corp.)
B, A group of totem poles, fluted step-growth towers in Giant's Hall, Luray Caverns. (Copyrighted by Luray Caverns Corp.)

Plate 19. Titania's Veil in Luray Caverns. A massive column formed through the union of stalactites and stalagmites. Stalactites of different ages hang from the ceiling. (Copyrighted by Luray Caverns Corp.)

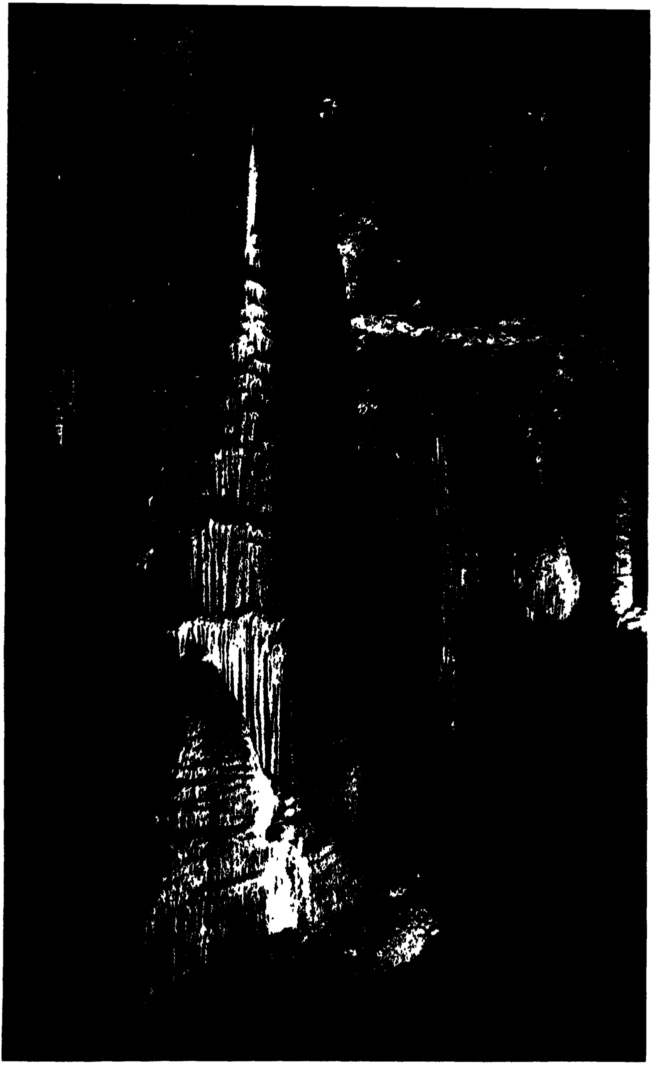

Plate 20. Leidy Column, a giant columnar intergrowth in the Blanket Room, Luray Caverns. Note the profuse growth of stalactites on the ceiling here. (Copyrighted by Luray Caverns Corp.)

than 3 miles of passageways have been explored, but at present only about 1¼ miles are open to visitors. New chambers and undeveloped channels are being constantly investigated, but no immediate additions are planned to the present tour which is confined mainly to two levels, and is circuitous but continuous. As is the custom in all of the caverns of Virginia many of the larger chambers and numerous individual objects or fantastic displays have been named in honor of some person, or after some place or event.

Luray Caverns are in the Nittany dolomite of the Beekmantown group (Fig. 15 and Table 3).

From the vestibule at the foot of the entrance stairway to remote rooms and channels at the far end of the Palace of Splendors and the Ball Room, the chambers and corridors offer a spectacular array of interesting and multicolored travertine formations. The spaciousness of the rooms and the immensity and variety of the travertine formations are, perhaps, the more impressive and striking features of Luray Caverns. Columns and draperies of ponderous size and matchless beauty are entwined or surrounded by groups of smaller graceful forms, with expansive masses of flowstone and dripstone blanketing the side walls and banking connecting halls and intersecting passages. The Cathedral is an example of the impressive groups of travertine formations to be found in Luray Caverns (Pl. 17).

Space does not permit a detailed account of all of the interesting and beautiful features, nor is it possible to describe adequately all of the distinctive characteristics of these caverns. An attempt will be made to point out those features of interest to the greatest number of visitors and to note others of scientific interest.

Entrance Avenue is a colorfully decorated chamber about 225 feet long, 40 feet wide, and 18 to 20 feet high. It is a fitting and particu-

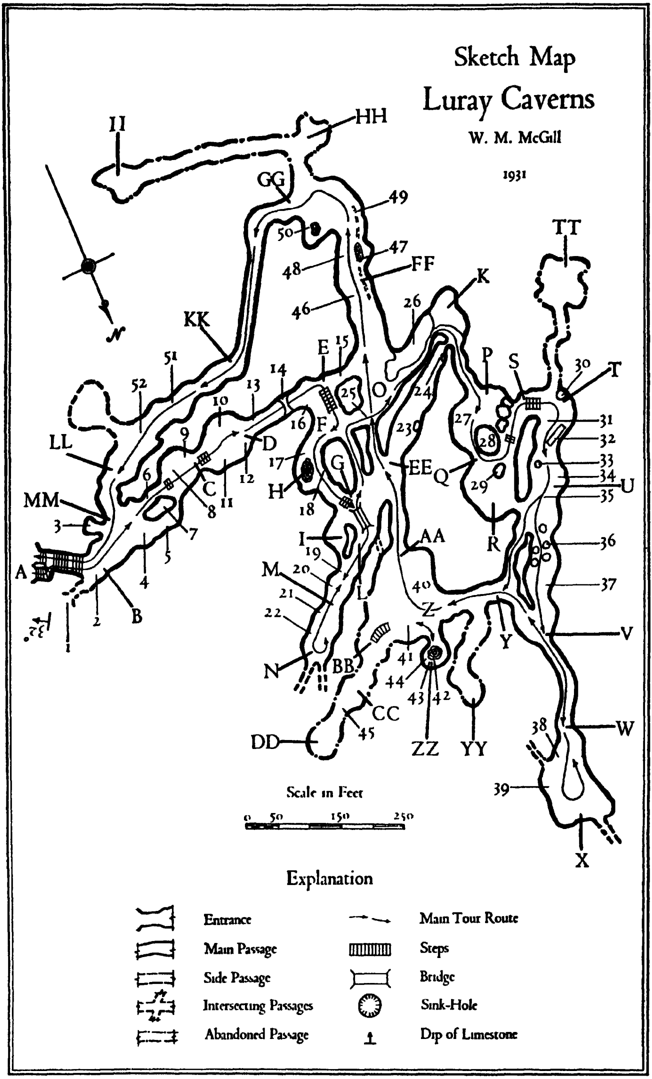

Figure 14.—Sketch map of Luray Caverns

larly pleasing introduction to the many beautiful rooms and chambers beyond. At the eastern end of this room, to the right of the entrance steps, is the Discovery Gate through which the original entry to the subterranean passages was gained. Probably the most impressive feature of Entrance Avenue is the coloring of the varied travertine deposits. Clusters of gray, apparently mouldy, stalactites fringe narrow, elongate crevices in the ceiling. Groups of graceful, slender stalactites resembling draperies, in harmonious tints of gray, white, brown and yellow, frequently streaked with green and orange, adorn the ceiling, and terraces of brown, yellow, gray and orange flowstone bank the side walls. Washington's Column, a massive intergrowth of stalagmites, approximately 40 feet long, 20 feet wide, and 18 feet high, occupies a dominant position at the west end near the Vegetable Garden. It is but one of the many large, sparkling columnar intergrowths to be found in Luray Caverns. This chamber contains also examples of undercut banks along the walls and clusters of dry, gray, spongeous growths and curiously shaped, netlike, brown veinlets, curiously resembling tangled masses of deeply rusted wire, on the walls and ceiling. These curious metal-like forms are undissolved fragments of siliceous veins in the limestone.[24]

The Vegetable Garden (Pl. 40) is one of the most interesting and realistic group scenes in the caverns. It is a small alcove thickly filled with a variety of small stalagmites and grapelike clusters of nodular concretionary masses. The low ceiling is picturesquely studded with slender tinted stalactites and attractive small etched and eroded forms.

Leaving the Vegetable Garden and descending about 15 feet, one enters the Amphitheatre, formerly the bed of an ancient stream. Here is seen a graceful array of stalactites along an enlarged joint in the ceiling, and undercut flowstone benches and balconies. This room contains also much stream-deposited material, such as cave dirt and cave silt with

which this and other parts of Luray Caverns were, in places, deeply filled. The walls of this chamber are thickly blanketed with flowstone and here, near Natural Bridge, is found the Fish Market, one of the many realistic groups of drapery formations to be seen in the caverns of Virginia (Pl. 43). A row of graceful, furrowed, fin-shaped draperies, averaging from 1½ to 2 feet in length, hangs from a bench covered with flowstone and closely resembles a string of fish.

Turning to the right at the end of the Amphitheatre, one leaves the abandoned channel of Muddy Lake, which continues in a southwest direction, to ascend by a concrete stairway to the Elfin Ramble, some 18 feet higher. This once spacious chamber has been largely filled with transported silt and clayey material until now the ceiling is, in places, less than 6 feet above the floor. As the maximum dimensions are about 120 by 350 feet, it is one of the largest chambers in the caverns, and one which offers a most extensive view of the underground channels of this cavern system. From here passages radiate in several directions to the numerous spectacular chambers and beauty spots accessible from this central picturesque "plateau."

At the top of the stairway from the Amphitheatre a circuitous path to the right leads through a narrow passage to Dream Lake, one of the most enchanting scenes in this fairy wonderland. It is a pool of crystal-clear water, nearly 40 feet long, some 30 feet wide and about 1 foot deep. The artistically etched ceiling above it is hung with myriads of graceful, scintillating stalactites ranging in length from a few inches to 2 feet and the nearly constant drip of water from them breaks the surface of the lake into a multitude of tiny concentric ripples (Pl. 18A).

Of noteworthy scientific interest here is the deposit of cave silt about 3 feet deep, through which the passage along Dream Lake has been cut (Pl. 18A). Fragments of the flowstone sheet which covered

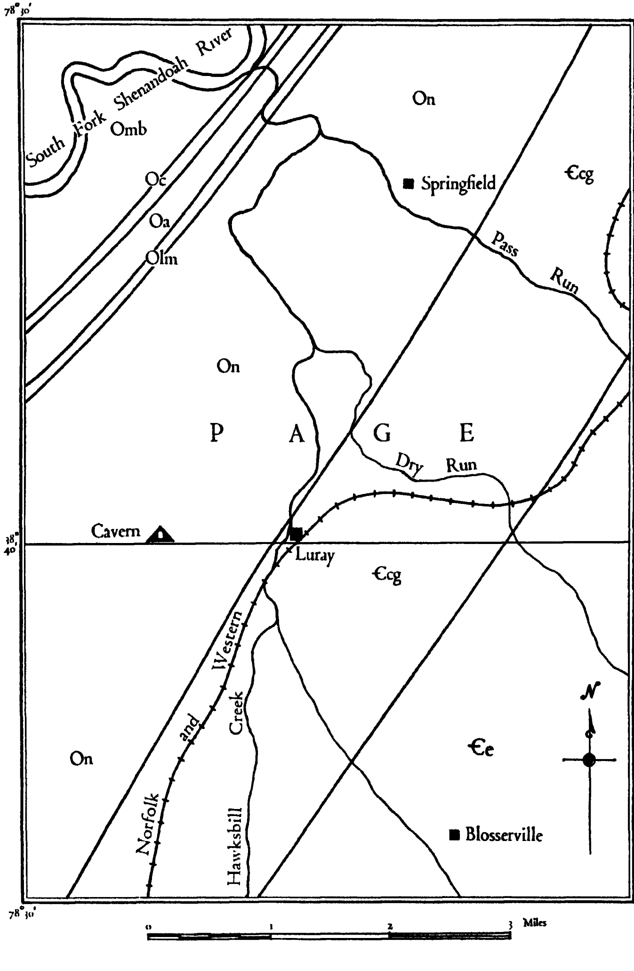

Figure 15.—Geologic sketch map of the environs of Luray Caverns. (By Charles Butts.) Ꞓe, Elbrook limestone; Ꞓcg, Conococheague limestone; On, Nittany dolomite; Olm, Stones River (Mosheim and Lenoir) limestones; Oa, Athens formation; Oc, Chambersburg formation; Omb, Martinsburg formation.

the silt deposit remain as ledges and alcove-like benches at intervals along the side walls. Above these benches occur several small wall pockets in which are found small clusters of wiry metalloid forms, similar to the siliceous vein deposits in Entrance Avenue.

From Dream Lake the path leads back to the Elfin Ramble and across it to a stairway leading down about 15 feet into Dante's Inferno, which can be crossed safely on a rustic footbridge. An impressive view of this magnificent underground chasm may be had from the bridge. Across the bridge one enters Hovey's Hall, a chamber about 100 feet long, 30 feet wide, and 35 feet high, containing an imposing array of stalactite, drapery and flowstone formations. Of particular interest in this room are the beautiful fin-shaped draperies, 6 to 12 feet in length, the Leaning Tower of Pisa, a picturesque stalagmite, and the curiously shaped helictites found on many of the larger stalactites. The helictites in Luray Caverns have been described by Dolley.[25]

Through a narrow passage between massive columns one reaches Statuary Hall, so named because of the interesting collection of calcitic statuary it contains. This room is about 65 feet long, 40 feet wide, and 45 feet high. The ceiling is particularly striking. From it projects an amazing variety of stalactites and drapery formations, one group of which attains a length of 20 feet. Tiers of flowstone encircle the upper side walls. At the northeast end of this chamber an abandoned overhead channel, about 30 feet above the floor level, continues in a general northeastward direction into the native limestone.

Returning to the Elfin Ramble another path leads through Skeleton Gorge, a passage some 10 feet wide, 160 feet long, and 20 feet high, where the skeleton of an Indian maiden was found embedded in flowstone. Continuing through the Swiss Cottage Pass, about 70 feet long, and again crossing Dante's Inferno, one passes safely through Fat Man's

Misery to enter Oberon's Grotto. This room is 60 feet long, 55 feet wide, and 50 feet high. Titania's Veil, the Big Column, and many eroded and broken stalactite-stalagmite columns of enormous size are among the spectacular displays found in this chamber (Pl. 19).

In the Blanket Room, as may be imagined, the flowstone has the form of a realistic display of blanket-like drapery. A massive hollow column with a circumference of 120 feet has been christened the California Redwood Tree. Another giant stalactite-stalagmite form is Leidy Column (Pl. 20). An abandoned channel crosses this chamber about 50 feet above the floor.

Leaving the Blanket Room and turning to the right, one descends by a concrete stairway into the Throne Room which is 60 feet long and 35 feet high. This is another "show spot" and contains some of the most picturesque travertine formations to be found in these caverns. Leaning towers and terraced columns rise majestically from the floor, with flowstone terraces banking the side walls. Blanket and fin-shaped draperies, a variety of stalactites, and etched limestone projections adorn the ceiling.

From the Throne Room the path leads down into Cathedral Hall, 70 feet long, 50 feet wide, and 35 feet high. Here are the Organ, the Chimes, the Fallen Column, and many convincingly realistic statuettes. Massive terraced and fluted stalagmite-pillars, castle-like intergrowths and folds of blanket draperies in a rich palette of colors delight the eye and stimulate the imagination (Pl. 17).

Next is Giant's Hall, the most spectacular chamber in Luray Caverns. It is 150 feet long, 80 feet wide, and 50 to 70 feet high. A faint impression of the magnificence, variety, profusion and size of the formations here may be obtained from Plate 18B. Terraced minarets, leaning towers, slender, graceful pillars and massive fluted step-growth columns project from the floor or rise abruptly from ponderous ter-

ral Spring. (Copyrighted by Luray Caverns Corp.)

races of flowstone. Fascinating groups of richly tinted stalactites and drapery-like forms hang from the majestic ceiling. Here also is the Double Column, huge twin stalagmitic pillars. From the Giant's Hall an abandoned overhead passage extends northeast on approximately the same level as that of the Blanket Room.

Through a somewhat sinuous narrow passage about 120 feet long, the path from Giant's Hall leads into the Palace of Splendors, the end room in the main section of the caverns. This chamber was added to the tour of the caverns in 1920. It is about 70 feet long, 30 feet wide, and 40 feet high. It contains some very attractive stalactite-stalagmite formations, numerous columns, and considerable flowstone. Among the most interesting features of this room are the nodular grapelike forms which encrust the stalactites, and the abandoned overhead stream channels which lead into or across this chamber at its far end. One of these appears to extend in the direction of the Throne Room.

From the Palace of Splendors one returns to Giant's Hall, from which an alternate path leads through a rather barren passage to the Ball Room. About midway of this passage a stairway leads up to the roof of Campbell's Hall, named after the discoverer of Luray Caverns and now abandoned as a part of the regular tour. The Ball Room is about 100 feet long, 60 to 70 feet wide, and approximately 65 feet high. It is another "show spot" and is probably the most admired chamber in the caverns. The floor is remarkably level, the walls are thickly and artistically banked with flowstone, and the ceiling is one of the most beautiful in the caverns (Pl. 21).

In a small alcove just off the Ball Room is Coral Spring, a most interesting tiered rock fountain bordered by groups of round-topped stalagmites, above which hangs an attractive group of fluted draperies. Near the Ballroom are Miller's Hall and Collin's Grotto, two small

rooms, which have also been abandoned as a part of the regular tour.

Leaving the Ballroom by a narrow tunnel one recrosses Dante's Inferno, passes beneath the bridge across Elfin Ramble and Skeleton Gorge, and walks along Sacred River through the attractive Silver Sea Corridor and several smaller circuitous passages to Stebbins Avenue. This route embraces the recently developed portion of the caverns and leads back to Entrance Avenue which now becomes Exit Hall. Stebbins Avenue is a very pretty chamber and contains some interesting travertine formations, as well as evidences of stream erosion, such as several gravel-cut domes.[26]

From Entrance Avenue one retraces his way up the entry stairway and thence to the lobby of the lodge.

Massanutten Caverns

Massanutten Caverns are in eastern Rockingham County, about 6 miles east of Harrisonburg and about 2 miles north of the Spottswood Trail (Route 17) from which they are accessible via a macadam road (Fig. 3). They are in a hill on an anticline on the west side, and near the southwestern end, of Massanutten Mountain. They were discovered on November 5, 1892, and the discovery entry was named the Discovery Gate. These caverns were first opened in 1925 but it was not until 1926, upon the installation of an electric lighting system, that they were opened to the public. They are in the area shown on the Harrisonburg topographic map.

The entrance to Massanutten Caverns is about 15 feet above the floor of the Lodge on the flat at the foot of the hill. A small spring, probably fed by waters from a lower level, occupies a small sink at the foot of the hill about 60 feet west of and about 18 to 20 feet below the entrance to the caverns. Cub Run, about 40 feet distant, flows south-

east into the South Fork of the Shenandoah, which drains the southern end of Massanutten Mountain.

The main tour is made on one level, with not more than 20 steps to ascend or descend, the maximum difference in elevation of the floor throughout the caverns being less than 10 feet. The part open to visitors consists of two somewhat circuitous and parallel channels which branch suddenly from a single passage about 15 feet from the entrance, and unite in a single channel in Pharaoh's Palace, about 250 feet to the northeast. From here the single channel extends in a winding northeast and northwest course to the Blue Room alcove at the end of Aladdin's Palace, the last room on the main level (Fig. 16). From the entrance to the Cretan Labyrinth to the far end of Aladdin's Palace is a distance of about 430 feet. The total length of the circuit through all of the developed passages is approximately 1,200 feet. The caverns are excavated in the Stones River group (Mosheim and Lenoir limestones) of early Ordovician age (Fig. 17 and Table 3).

Two levels are known to exist below the main tour level, and parts of them are said by the guides to contain rooms and corridors similar to the developed level and to be richly adorned with beautiful deposits of travertine. It is not very probable that any large channels occur above the main level, as the summit of the hill is not more than 60 to 70 feet above its floor.

The developed passages consist of a connected series of rather narrow short and long corridors, numerous alcoves and moderately large rooms. The highest ceiling is not more than 25 feet above the floor. The average width of the narrower passages varies from 15 to 30 feet. The Ball Room is the largest room in the caverns with a length of about 100 feet.

Of outstanding appeal in Massanutten Caverns are the profusion

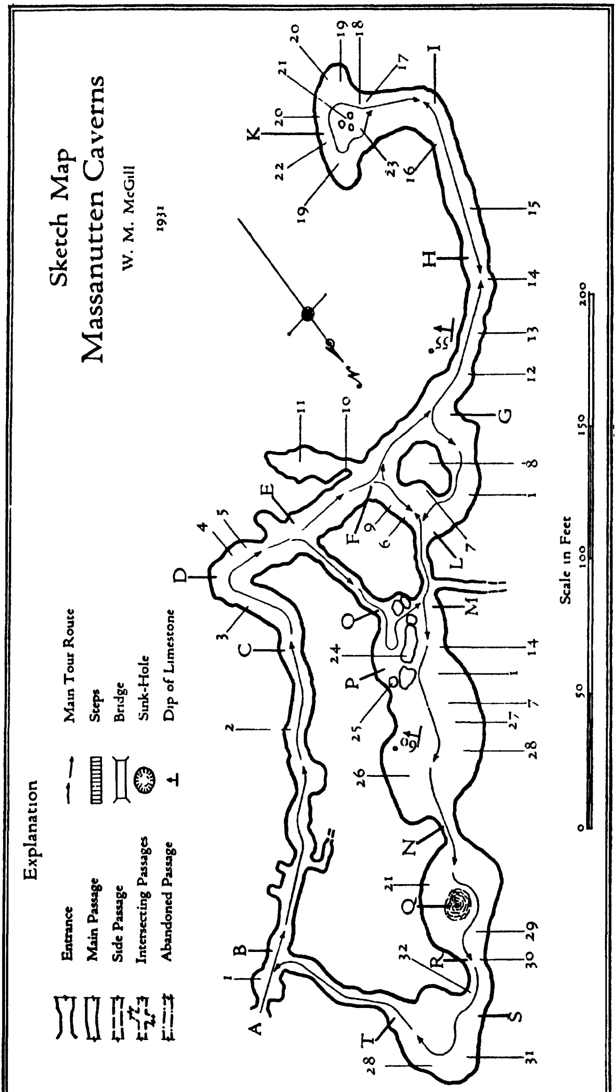

Figure 16.—Sketch map of Massanutten Caverns

Figure 16

EXPLANATION

- A-B. Entry Alcove.
- B-C. The Cretan Labyrinth.
- C-D. Star Chamber.
- D-E. The Meat Market.
- E-O. Passage to Wonderland.
- E-F. Lovers' Lane.
- F-G-L. Pharaoh's Palace.
- G-H. Skeleton Pass.
- H-I. Hanging Gardens.
- I-K. Aladdin's Palace.
- L-M. Fat Man's Misery.
- M-N. The Ball Room.
- M-O. Passage to Wonderland.
- O-P. Wonderland.
- N-R. Sampson's Fury.
- Q. Mirror Lake.
- R-S. The Pillared Way.
- S-T. Fairyland.
- T-B. Exit Passage.

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1. Peculiar bulbous stalactites.
2. The Art Gallery.
3. Star (Stalactite)-studded ceiling.
4. Broken Columns.
5. Columnar intergrowths.
6. Soda-straw stalactites.
7. Profusion and variety of stalactite forms.
8. Diamond Column.
9. Soda Fountain.
10. The Cottage Window.
11. The Unnamed Room.
12. The Jewel Box.
13. Broken travertine forms.
14. Stalactites in rows along joints.
15. Abandoned channels in ceiling.
16. Hanging Bridge.
17. Cup-topped stalagmites.
18. Limestone pendants.
19. Abandoned channels in floor and along walls.
20. Flowstone cascade.
21. Giant Teeth.
22. Lily Pads.
23. Stalactites and stalagmites apparently coated with pebbles.
24. Elephant Rock.
25. Indian Wigwam.
26. Shield.
27. Bacon-strip drapery.
28. Beet- and potato-shaped stalactites.
29. Icicle Avenue.
30. Twin stalagmites.
31. The Split Column.
32. Vulcan's Forge.

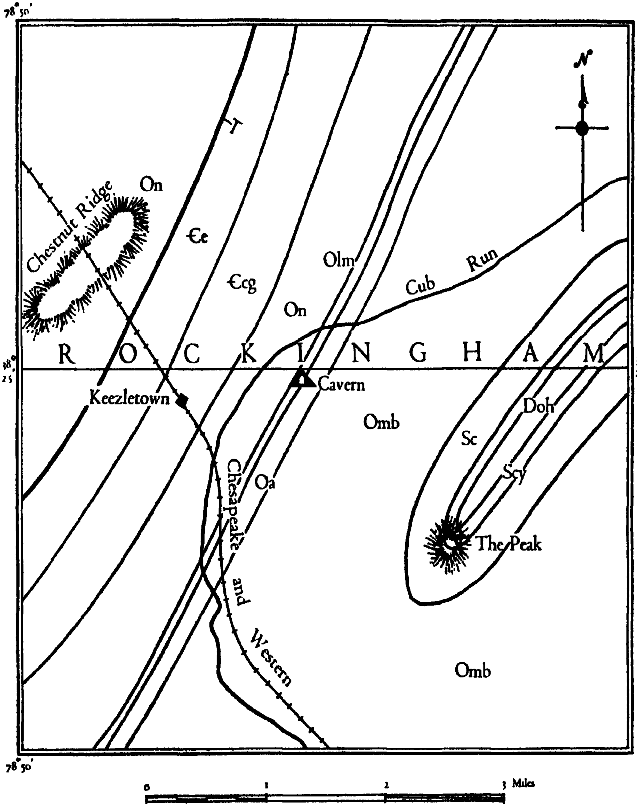

Figure 17.—Geologic sketch map of the environs of Massanutten Caverns. (By Charles Butts.) Ce, Elbrook limestone; Ccg, Conococheague limestone; On, Nittany dolomite; Olm, Stones River (Mosheim and Lenoir) limestones; Oa, Athens formation; Omb, Martinsburg formation; Sc, Clinch sandstone and Clinton group; Scy, Cayuga group; Doh, Helderberg group and Oriskany sandstone.

and variety of the stalactitic forms which bedeck the entire caverns. From the entry alcove to the far corner of Aladdin's Palace, and from Pharaoh's Palace, through the Ball Room, Sampson's Fury, Fairyland, and back to the entrance, Massanutten Caverns contain a dense growth of dainty, delicate, and graceful travertine formations. The ceilings are thickly studded with aggregates of dainty, graceful stalactites of great variety and unexcelled beauty (Pls. 24A and 37A).

From the Entry Alcove, one walks northeast along the picturesque winding Cretan Labyrinth, which contains many realistic animal and human shapes, to the Star Chamber. From this circuitous passage, several small channels along the base of the walls lead to lower undeveloped passages. Here are seen also shelves, benches and undercut banks at intervals along the walls. The development of stalactites along joints in the ceiling and the formation of several groups of twin stalactites are well illustrated. Small intersecting and abandoned stream courses are well shown in this corridor.

Entering the Star Chamber, one is captivated by the beauty and profusion of the tiny stalactites with which the ceiling is studded, justifying its name. Several examples of broken columns occur here, a rather massive one occupying the center of the chamber. The formation of stalactites of two ages, a younger set upon an older broken group, is among the interesting features of this room.

In passing through the Meat Market, one notes the formation of stalagmites upon broken columns and the growth of stalactites from shields. Here are exposed also ribbon-like veins of calcite in the wall. An alternate side passage to the right leads direct into Wonderland. By way of Lovers' Lane one reaches Pharaoh's Palace.

Pharaoh's Palace marks the northern union of two separate channels, or the branching into two parallel channels of the original single

course which was excavated from Aladdin's Palace to Pharaoh's Palace. This chamber is characterized by the splendor and variety in coloring and form of the many picturesque step-growth columns, long, slender stalactites, graceful draperies and much flowstone with which it is adorned (Pl. 37A).

From Pharaoh's Palace one may look through a picturesque "cottage window" into the Unnamed Room which contains a variety of artistically tinted stalactites, stalagmites and slender columns. The floor and walls are picturesquely coated with flowstone and dripstone.

Passing next through Skeleton Pass and the enticing Hanging Gardens of Babylon, one enters Aladdin's Palace, the last room in the cavern. Here one finds formations of a different type from those in other passages and chambers. The stalactites are longer and thicker than elsewhere. Here is also evidence of stream erosion, at least in the early development of the caverns, as ancient channels are prominently preserved in the ceiling and on the walls. From the ceiling protrude oddly shaped water-carved remnants of the limestone and several long pendant forms resembling giant teeth (Pl. 22). The columns in the center are rather profusely coated with clusters of small pebble-like concretions. The finlike ends of the draperies and the slender stalactites are adorned with many delicately shaped fantastic helictites. Wavy basin-shaped corrugations, 1 to 4 inches deep, occur on the floor beneath clusters of stalactites.

Retracing the single passage to Pharaoh's Palace, one observes again the beauty of the sparkling Diamond Column and the profusion of pure white, slender, strawlike stalactites that occur here. Wonderland is next reached through a narrow passage from a corner of the Ball Room near Pharaoh's Palace. This is one of the most beautiful chambers in the caverns and contains several interesting, odd-shaped varieties of stalac-

Plate 22. Peculiar stalactites and pendants in Massanutten Caverns. An interesting display of the varied formations occurring in Aladdin's Palace. Some of these giant pendants are from 12 to 15 feet long.

Plate 23. Reflected beauty in Mirror Lake in Massanutten Caverns. A variety and profusion of graceful stalactites are suspended from the ceiling above the lake. Note the group of postlike stalagmites beyond the lake.

Plate 24. A, Stalactite-studded ceiling in the Ball Room in Massanutten Caverns. A variety of odd, bulbous stalactites occurs here.
B, Stalactites, stalagmites and columns in Massanutten Caverns. Note the Split Column and the long, spear-stalactites.

Plate 25. Grotto of the Gods in Shenandoah Caverns. Shows the thick, terraced rolls of flowstone on the walls and the folded blanket draperies and canelike stalactites fringing inclined channels.

tites not evident in other rooms. Some are beet-shaped, some resemble suspended wasps' nests and others look like pears, apples, or potatoes impaled on long, slender, petrified spikes. The travertine formations of Wonderland are probably more colorful than those in other parts of the caverns. Red, white, brown, pink and gray predominate, though many other tints occur. The ceiling is the highest in the caverns, being 40 feet above the floor. Here, too, are the largest columns, one of which is reported to be 40 feet around the base. Many realistic forms may be seen on the walls and ceilings. The development of stalactites and draperies along joints is well illustrated in Wonderland and in the Ball Room, which is next entered through a narrow passage, aptly termed Fat Man's Misery.

The Ball Room is one of the "show spots" of Massanutten Caverns, for it contains a large menagerie of travertine animals. The ceiling shows a well-preserved stream channel and overhead vents prominently developed along joints at right angles to the strike of the limestone (Pl. 24A).

Mirror Lake in Sampson's Fury, just beyond the Ball Room, is a strategically located reflector for the beauties of the ceiling above. It is a most engaging and beautiful underground scene and, with the aid of the artistic and changing light effects, creates a never-to-be-forgotten image of the wonderful natural beauty of Virginia's underground marvels (Pl. 23).

Sampson's Fury is characterized by stalactites, stalagmites and columns that are artistically and in places thickly coated with pebble-like concretionary forms resembling rough stucco.

From Sampson's Fury the course leads through Icicle Avenue containing myriads of stalactites, and the Armory with its stalactitic shields, swords and spears, to Fairyland. Here occur several picturesque taper-

ing columns and a variety of slender, elongate stalactites. The formations in this chamber are also coated with pebble-like growths. One of the most interesting features is the Split Column, which is thought to have been riven by the pressure of a heavy block of limestone. The ceiling is very pretty, being copiously adorned with interesting stalactitic and drapery forms (Pl. 24B). From Fairyland one follows a narrow passage to the Entry Alcove which now becomes the exit passage.

Shenandoah Caverns

About 3 miles north of New Market and about 1½ miles west of the Lee-Jackson Highway (Route 11), accessible by a macadam road, are the Shenandoah Caverns (Fig. 3). They are in Cave Hill, a short distance west of the North Fork of Shenandoah River, in an area which is shown on the Woodstock topographic map. Discovered in 1884 during the building of the Valley division of the Southern Railway, the caverns were formally opened to visitors in May, 1922.

As in all the other caverns of Virginia, there is much legend attached to their early history. Tradition has it that Shenandoah Caverns were known to the Indians who inhabited the Valley before the coming of the white man, and that they were the hiding place of refugee braves and scattered bands of red men during many clashes between the warriors of the several tribes that roamed the Valley region. The name Shenandoah given also to the beautiful Shenandoah Valley is of Indian origin, and means "Daughter of the Stars." It has been stated that the skeleton of an Indian brave was found on a rock-ribbed bench in one of the passages by a white explorer many years before the existence of these caverns was known to any except the pioneer settlers.

These caverns comprise a chain of high-vaulted chambers, many of considerable length, connected by short, narrow passages excavated on

three levels. The main tour of the developed part is largely on one level, with but slight changes in grade where deposited material has accumulated on the floors. The maximum difference in elevation along the main passages is probably not more than 20 feet. From the main corridors, several passages lead to detached chambers at somewhat higher elevations. The length of the tour from the entrance steps to Rainbow Lake, at the extreme end of the present development, is about 1,600 to 1,700 feet. The complete circuit, including the several side chambers, is approximately 3,900 feet. Within the past year new rooms have been explored and some of them added to the tour. The main developed passages resemble, in plan, a huge letter S (Fig. 18).

Shenandoah Caverns are in the Conococheague limestone of late Cambrian, or Ozarkian, age (Fig. 19 and Table 3). The limestone has not only been folded but has undergone further deformation by faulting. Joints are prominent in parts of the main channels. Entrance Avenue and the passage from Giant's Hall to Rainbow Lake are along the strike of the limestone, whereas the longer connecting series of high-vaulted rooms is along a fault. It is believed that the two strike channels were excavated by two separate streams flowing along strike joints in the fractured limestone. Upon encountering the fault the course of each stream was deflected and, after the union of the two streams, the channel along the fault was enlarged. The stream which occupied the fault passage most probably reached the surface through the rock-filled, undeveloped channel which leads from the southeast end of the Grotto of the Gods to an abandoned stone quarry on the east slope of Cave Hill, through which the original entrance to the caverns was gained. The abandoned and rock-filled passage at the northeast end of Entrance Avenue leads also to the stone quarry. The unevenness of the floor of

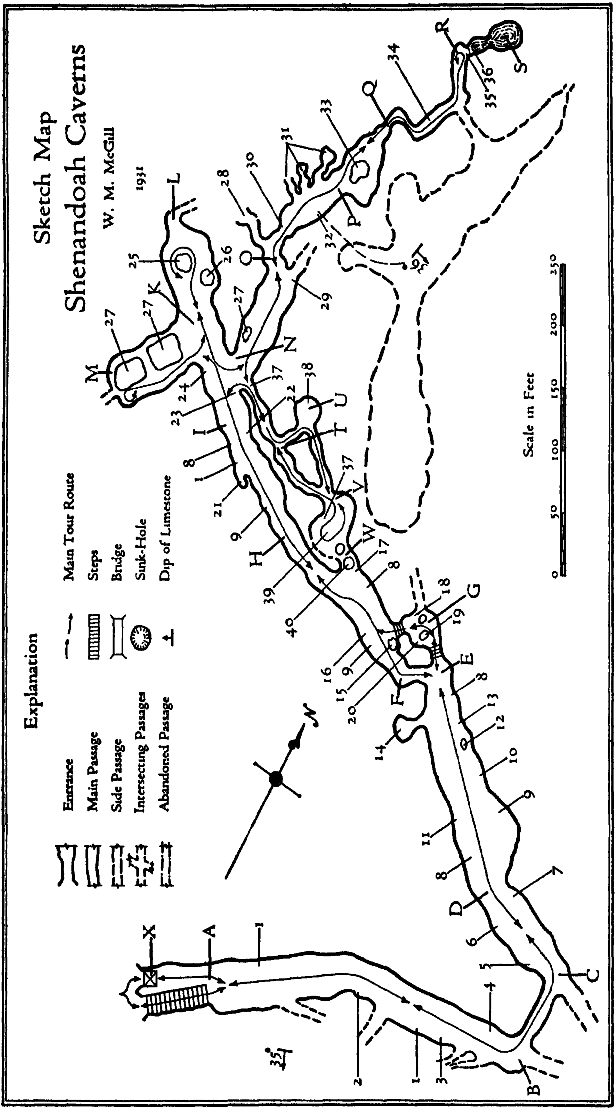

Figure 18.—Sketch map of Shenandoah Caverns

Figure 18

EXPLANATION

A-B. Entrance Hall.
B-C. Short Passage.
C-D. Grotto of the Gods.
D-E. Vista of Paradise.
E-F. The Pass.
F-H. Druids' Hall.
G. Napoleon's Mausoleum.
H-I. Cascade Hall.
I-K. Giant's Hall.
K-L. Tower Room.
K-M. Glacial Room.
N-O. Snyder's Hall.
O-P. Blue Room.
P-Q. Castle Hall.
Q-R. Winding Passage.
R-S. Rainbow Lake.
N-T. Narrow Passage.
U. Indian Room.
T-V., U-V. Narrow Passage.
V-W. Dome Room.
X. Elevator.

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1. Breakfast-bacon draperies.
2. Balcony Falls.
3. Dante's Inferno.
4. Textile Hall.
5. Suspended balcony.
6. Undercut banks and walls.
7. Chasm-like rifts in ceiling.
8. Large pendant draperies.
9. Blanket rolls of flowstone on walls.
10. The Mosque.
11. Nodular concretionary encrustations.
12. Goat Head Rock.
13. Alpine Peak.
14. Beyond the Veil.
15. Colonial Column.
16. Fluted and terraced columns.
17. Broken travertine formations.
18. The Cathedral.
19. Statue of Napoleon.
20. Stone Forest.
21. The Stage.
22. Diamond Cascade.
23. Flowstone, draperies and stalagmites apparently coated with pebbles.
24. Shields.
25. Balanced Rock.
26. The Leaning Tower.
27. Large, broken, limestone blocks.
28. Frost King's Palace.
29. Flowstone cascade.
30. Abandoned stream channels.
31. Alcoves.
32. Limestone pendants.
33. Cardross Castle.
34. The Tunnel.
35. Helictites.
36. Tusklike stalactites.
37. Fluted draperies.
38. Indian Wigwam.
39. Giant draperies.
40. Capitol Dome.

the fault channel is due in part to the accumulation locally of broken limestone blocks and transported material.

It is claimed that the floor near the brass plate on Goat Head Rock in the Vista of Paradise, established by the United States Engineer Office, is the lowest point in the caverns. This plate is 941.5 feet above sea-level and about 90 feet below the entrance lobby of the Caverns Inn. The highest point on the main tour is approximately 175 feet above the average level of the main floor level. The summit of Cave Hill is about 160 feet above the entrance and about 215 feet above the main floor level.

From the entrance on the lower floor of the Caverns Inn, one descends about 60 feet by an elevator or a concrete stairway to the main tour floor. At the base of the stairway begins Entrance Avenue which extends along the northeast strike of the limestone for approximately 300 feet. The width of this corridor varies from 18 to 40 feet, and its height ranges from 10 to 30 feet. Several small undeveloped inclined passages lead from the base of the right wall, generally along the dip of the limestone, to unexplored channels at lower levels, which drained most probably to surface streams at lower points on Cave Hill. Exposures of the bedding planes along the ceiling and left wall of this corridor show a strong southeast dip. Here are several realistic strips of "breakfast bacon" (Pl. 44A), and Balcony Falls and Dante's Inferno. The rear part of Entrance Avenue has been named Textile Hall.

At the end of Textile Hall, just beyond Dante's Inferno, a narrow tunneled pass leads northward about 40 feet into the Grotto of the Gods, the first of the closely connected high-ceilinged chambers which extend northwesterly along the fault channel. Along the left wall of this chamber, about 3 feet above the floor, is a suspended balcony or shelf on which has grown an attractive array of stalagmites. Under-

cut banks are also noted. The height of the ceiling in this and several of the connecting chambers is, in places, more than 70 feet. It is claimed that some of the narrow (sloping to vertical) chasmlike rifts in the ceiling here and in the Vista of Paradise extend upward for more than 100 feet above the floor. The development of oblique intersecting channels of great length is well shown in these two chambers and in the Frost King's Palace. The walls and ceiling of this chamber and of the Vista of Paradise, Druids' Hall, Cathedral Hall, and Giant's Hall beyond, are profusely decorated with thick coatings of flowstone and giant drapery stalactites. The thickness and profusion of these deposits testify to the great volume of water that flowed and seeped into these chambers from higher channels (Pl. 25).

Nodular concretionary forms encrust the billowing rolls of flowstone throughout the larger corridors and chambers and, in places, give a stuccoed appearance to the walls. Groups of helictites and clusters of dainty, feathery aragonitic growths adorn the lower end of many large draperies and stalactites.

The Vista of Paradise is similar to the Grotto of the Gods and is really a continuation of that chamber. It is lavishly adorned with massive drapery and stalactitic forms and the walls are sheeted with extensive and picturesque flowstone coatings. Many realistic and several fantastic stalagmitic or dripstone images project from the walls, ceiling and floor. Here also are found other examples of breakfast-bacon draperies and parts of broken stalagmite pillars of large size. About midway of this chamber on the right of the pathway is Goat Head Rock, which marks the lowest point in the caverns. Near the end of this chamber a narrow opening in the left wall leads into a pretty little alcove containing a pleasing array of stalagmitic, stalactitic and drapery growths, romantically named Beyond the Veil.

At the end of the Vista of Paradise concrete steps lead up into Napoleon's Mausoleum, which is also reached from Druids' Hall. Turning sharply to the left, one enters a narrow, short passage which leads into Druids' Hall, another high-domed chamber extending in a northwesterly direction and considered by many who have seen it to be the most attractive chamber in these caverns. Gigantic stone pillars and graceful dripstone columns flank this room, while from the ceiling hang draperies and stalactites of considerable length and much beauty. Here also are found undercut benches and suspended balconies. On the right of the entrance, near the steps to Napoleon's Mausoleum, is the Colonial Column, a feature of unusual distinction. Here one has a most engaging view of the Capitol Dome and the gigantic fluted draperies which overhang and surround it (Pl. 26).

In Napoleon's Mausoleum are found many interesting and realistic stalactite and stalagmite images and attractive groups of draperies. One of the most lifelike of these is the marble statue of Napoleon which adorns a niche high on the wall of this cathedral-like chamber. The ceiling is the highest in the developed part of the caverns.

From Druids' Hall one enters next Cascade Hall, named from the massive Diamond Cascade (Pl. 27A), a sparkling white dripstone and flowstone deposit which graces this spacious chamber. In an alcove in the left wall, nearly opposite the Cascade, is the Stage, a miniature theatre setting in stone of much beauty. Groups of draperies of great length and considerable attractiveness adorn the right wall and ceiling.

Giant's Hall is one of the largest chambers and contains some interesting formations. The right wall is profusely adorned with a stuccoed-appearing deposit of flowstone, while gigantic pebbly coated and fluted draperies 20 feet long hang from the ceiling. Here occur other

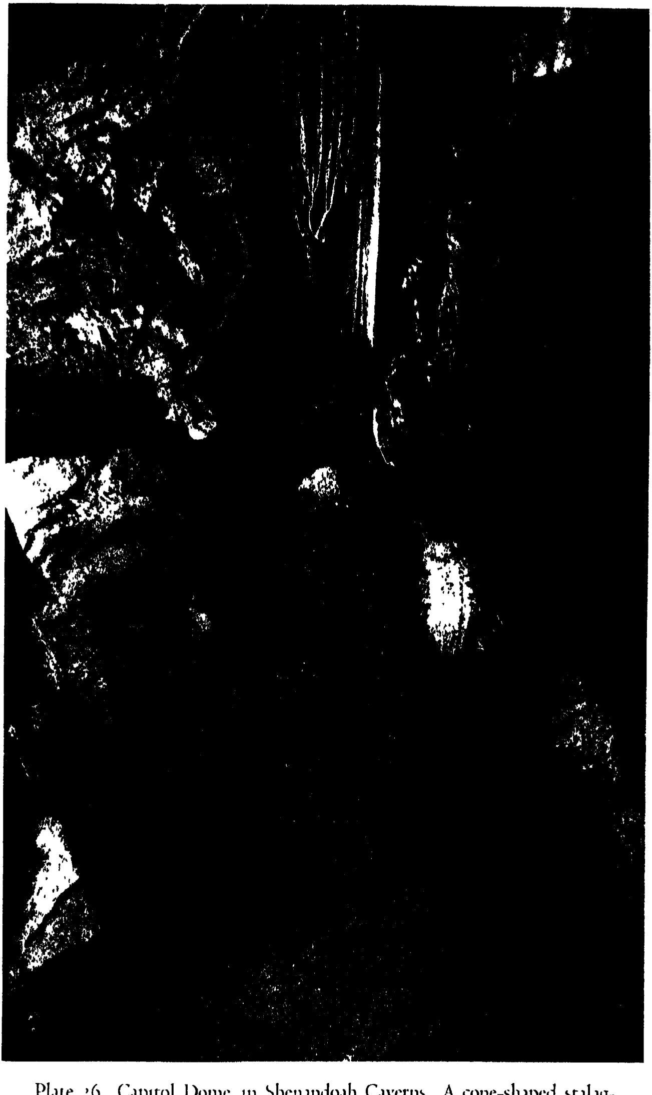


Plate 26. Capitol Dome in Shenandoah Caverns. A cone-shaped stalagmite 8 feet high, banked with flowstone and overhung by a picturesque group of draperies. (Courtesy Marken & Bielfeld, Inc.)

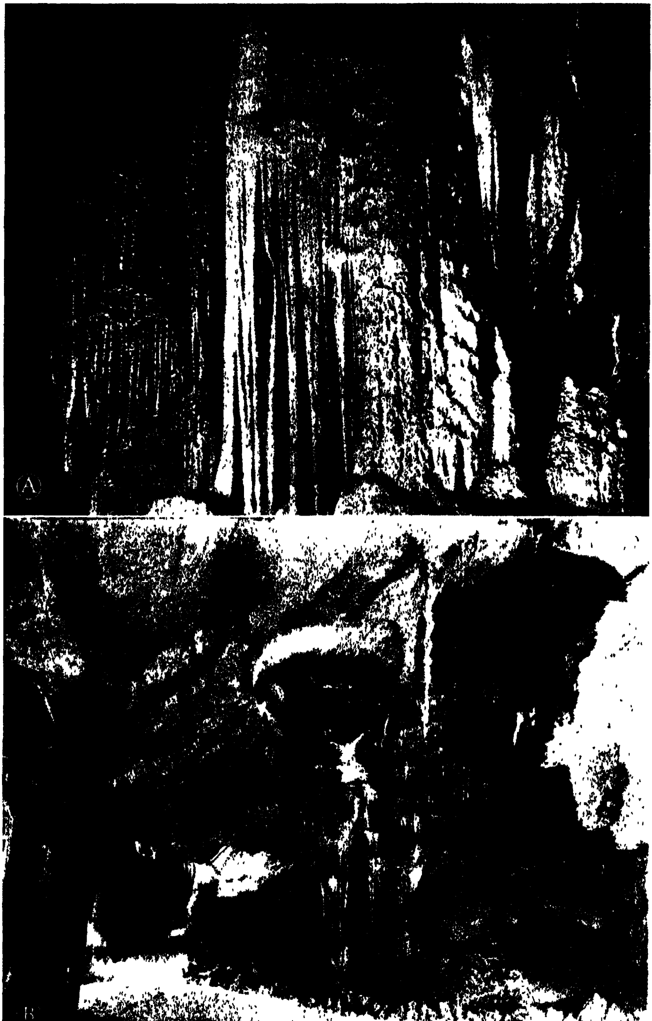


Plate 27. A, Diamond Cascade, a massive flowstone deposit in Shenandoah Caverns. The multitude of crystal faces sparkles like jewels.
B, Snyder's Hall, in Shenandoah Caverns, showing three abandoned channels in the ceiling and a huge flowstone terrace.

strips of breakfast bacon and two shields, one partly buried in a flowstone-covered ledge, the other projecting outward from the wall. In the center of the ceiling occur rifts and fissures which probably extend to abandoned upper channels.

In the Glacial Room, which extends southwesterly from Giant's Hall, are several attractive parallel bacon-strip draperies. The greater part of this room is occupied by two large limestone blocks which were loosened from the ceiling by percolating waters seeping along joints, and perhaps in part by some slight earth movement. In the far end of Giant's Hall, which has been termed the Tower Room, may be seen other examples of the large blocks that have been dislodged or broken from the ceiling by ground-water action. One is called Balanced Rock. Here also occurs the Leaning Tower, a very realistic formation. At the northwest end of the Tower Room a small abandoned inclined passage leads upward in the direction of Rainbow Lake, probably to a higher channel.

Nearly opposite the entrance to the Glacial Room the path leads in a northerly direction into Snyder's Hall, the first room in the second of the main passages excavated along the strike of the limestone. Of special interest here are the parts of three former stream channels eroded in the ceiling, each at a slightly lower level (Pl. 27B). At the end of this chamber, on the right, may be seen an example of the amount of flowstone that is sometimes deposited at the convergence of two underground channels.

Turning to the left at the end of Snyder's Hall, one passes on the left the interesting Frost King's Palace and enters the Blue Room. Of interest here are the three alcove-like side passages in the left wall, into each of which an abandoned inclined connecting channel leads from unexplored openings above. In the ceiling and along the left wall of this

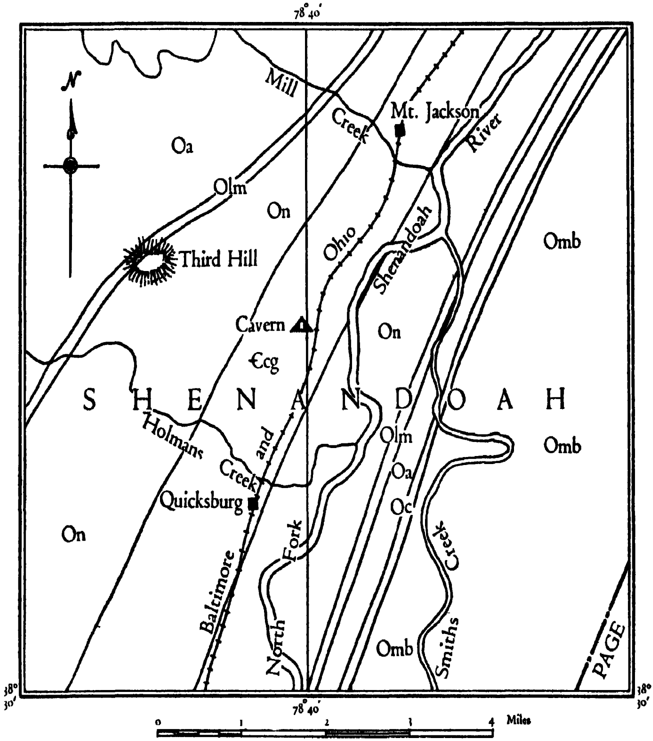


Figure 19.—Geologic sketch map of the environs of Shenandoah Caverns. (By Charles Butts.) Ꞓcg, Conococheague limestone; On, Nittany dolomite; Olm, Stones River (Mosheim and Lenoir) limestones; Oa, Athens formation; Oc, Chambersburg formation; Omb, Martinsburg formation. (Oa to northwest includes other formations.)

a wonderful panorama of the Shenandoah Valley and its bordering mountains on the northeast and southwest. Many spots of appealing scenic beauty and several natural wonders are within a short distance.

Virginia Caverns

About 8 miles south of New Market and approximately 6 miles north of Harrisonburg a good road leads from the Lee Highway (Route 11) west about 800 feet to a picturesque rock lodge at the entrance to Virginia Caverns (Fig. 3). These caverns are in a small hill on an anticline a short distance west of Dry Fork, a tributary to the North Fork of the Shenandoah, into which it is probable that the stream from the caverns discharged. These caverns are in the area shown on the Woodstock topographic map.

Virginia Caverns are especially rich in historic interest and appeal. While their existence had been known for a long time, it was not until 1929 that they were opened to the public, under the name of Blue Grottoes. The caverns were used as a retreat by both Federal and Confederate troops during the Valley campaigns of the War between the States. Hand-carved rosters and artistically decorated scrolls containing the names of hundreds of soldiers of both armies are inscribed upon walls, columns and ceilings. Some of the individual inscriptions are of an even earlier date, to judge from the numerals "1818" inscribed after certain names and initials in Century Hall. Marks of pistol and rifle balls may be seen on the walls and on some of the larger travertine formations in certain of the corridors. The Soldier's Target, a large bullet-scarred column in Echo Hall, is a memorial of historic interest. One of the noticeable features in these caverns is the quantity of broken stalactites and stalagmites, probably to be attributed to the soldiers and done as a harmless pastime or in target practice. A large amount of sta-

ctitic and stalagmitic material was no doubt carried off by them as)uvenirs of their "cave life."

It is probable that the caverns were frequented by Indians prior to ıe settlement of the Valley by the white man. White pioneers knew ⁻ their existence, and tradition records that early residents of this part ⁻ the Valley used them as a refuge in times of distress or to escape assacre at the hands of roving Indians. In preparing the caverns for ıblic display during 1928 and 1929, the owners found, buried under veral inches of accumulated silt on the cavern floor, arrowheads, spear)ints, and ashes from ancient fires, indicative of early occupancy by dians. Bones of several small animals, such as inhabit caves or holes the ground, and part of the skeleton of a bat were also found.

Virginia Caverns consist of a continuous sinuous passage excavated ıiefly on one level and having a total length from the entrance to the ar of about 1,200 feet. Several developed or partly explored side chan-·ls and one large room, the Hippodrome, give a total length of about 600 feet to the complete tour (Fig. 20). The possible existence, at ıst along parts of the main course, of a second and higher level, is ›t likely, owing to the restricted height of the crest of Cavern Hill in ıich the caverns occur. Before the present entrance was opened, a ugh wooden stairway in a sink-hole at the far end of the caverns was ed as an entrance. This point is on the crest of the hill south of the esent opening at a surface elevation of about 1,175 feet. Because of use by the soldiers and early settlers this passage is known as Pioneers' ıtry or Soldiers' Entrance. The caverns are in the Stones River (Mosheim d Lenoir) limestone of early Ordovician age (Fig. 21 and Table 3).

The elevation of the floor at the rear of the caverns is about 1,260 :t and at the entrance to the Gothic Cloister approximately 1,235 :t. The old (Soldiers') entrance is at an elevation of about 1,250 feet

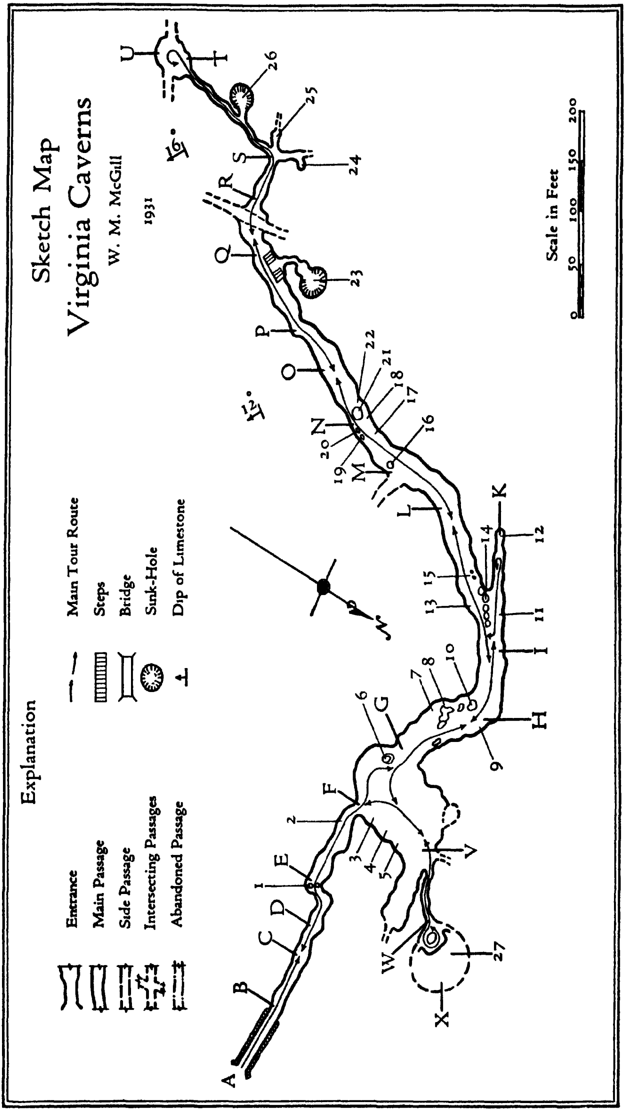


Figure 20 - Sketch map of Virginia Caverns

Figure 20

EXPLANATION

A-B. Entrance Passage. (Artificial.)
B-C. The Gothic Cloister.
C-D. Eaton's Pass.
E-F. Record Hall.
G-V. The Hippodrome.
G-H. Hanging Gardens of Babylon.
H-I. Echo Hall.
I-K. Aladdin's Palace.
I-L. "Stonewall" Jackson's Grotto.
L-M. Century Hall.
M-N. Thousand Island Corridor.
N-O. Fremont's Grotto.
O-P. Sheridan's Grotto.
P-Q. Gilded Grotto.
Q-R. The Rotunda.
R-S. Narrow Passage.
S-T. New Passage.
T-U. New Room.
V-W. Winding passage.
W-X. Underground Amphitheatre.

1. Twin Columns.
2. The Chimes.
3. The Zoo.
4. Flowstone terraces.
5. Stalactite-spiked shield.
6. The Broken Column.
7. Stalactite-drapery pendants.
8. The Portal.
9. Abandoned channels in ceiling.
10. Soldiers' Target.
11. Natural Bridge.
12. Aladdin's Lamp.
13. Suspended Balcony.
14. Row of columns under joints.
15. Stalagmite statues.
16. Tower of Babel.
17. Lily Pads.
18. Limestone pendants.
19. Mt. Vesuvius.
20. The Lone Column.
21. Registry Column.
22. Totem Pole.
23. Soldiers' Entry. (Sink-hole.)
24. Indian Room.
25. Cliff Dwellers' Alcove.
26. Sink-hole entry.
27. Fairyland.

and the floor just north of the entrance to Stonewall Jackson's Grotto is about 1,240 feet. The gradual slope from the rear to the present entrance indicates that the stream which excavated these caverns originally entered the limestone through small surface fissures or the sinkholes near the rear of the caverns. A northeasterly passage was excavated along the strike of the limestone, for a distance of about 700 feet to the northern end of Stonewall Jackson's Grotto. Here the stream followed a somewhat sinuous easterly course along a prominent east-west joint or a local change in the strike for a distance of about 450 feet, emerging as a spring feeding into Dry Fork at a point on the northeast slope of Cave Hill, probably near the present entrance.

The present entrance is through an artificial passage about 60 feet long, which leads from a rock-enclosed courtyard in the rear of the lodge to the Gothic Cloister, a remarkable example of a water-carved passage whose ceiling is shaped like a Gothic arch. This attractive corridor affords an inviting entrance to the corridors and chambers beyond (Pl. 29). It extends westward from the end of the artificial passage for about 80 feet to Eaton's Pass, which continues in the same direction for about 40 feet. From a joint along the middle of the arched ceiling hangs a picturesque row of short, broken stalactites.

At the end of Eaton's Pass, a short passage to the left leads into Record Hall, on entering which one passes between the Twin Columns. This is the first large room and contains several huge stalagmites. Near the far end of this chamber are the Chimes. From here one visits next the Hippodrome, the largest chamber in the caverns, with many fantastic deposits of travertine resembling animals and a graceful stalactite-spiked shield. Two vertical, pipelike channels on the north side and a prominent abandoned inclined passage leading into this room on its northeast side are most probably the channels through which much of

Plate 28. Cardross Castle in Shenandoah Caverns. A realistic, massive, stalagmitic intergrowth. The Castle is about 15 feet high.

Plate 29. The Gothic Cloister in Virginia Caverns. A natural arched passage of much beauty in the limestone. A row of broken, fin-shaped stalactites about 2 feet long extends along a joint in the ceiling.

Plate 30. The Portal, a natural gateway in Virginia Caverns. Shows the development of stalactites and stalagmites in rows along joints. Note the massive size of the stalagmite-columns on the right.

Plate 31. A, Thousand Island Corridor in Virginia Caverns. Note the "frost-coated" stalagmites, water-filled basins and flowstone terraces.
B, Registry Column, a large stalagmite in Virginia Caverns. On it are found the names of many Union and Confederate soldiers.

the thick deposit of silt, clay and debris which covers the original floor to a depth of about 4 feet was derived. This deposit is covered with a protective coating of flowstone, forming a terrace, through which the pathway has been cut.

From the Hippodrome one enters the interesting Hanging Gardens, passing close to the Broken Column, a large stalagmite. At the end of the Hanging Gardens one passes through the Portal, a picturesque natural passage between graceful stalactite-stalagmite columns, into Echo Hall. The Portal is considered by many to be one of the most attractive scenes in these caverns (Pl. 30).

Echo Hall, also called the Azure Room or Blue Crescent Corridor, is a circuitous conduit-shaped passage barren of travertine formations, except for a row of short, broken stalactites along a crevice in the ceiling (Pl. 34 A). Beyond Echo Hall is Aladdin's Palace, a narrow, picturesque side channel extending in a westerly direction for about 125 feet. Here are found several interesting water-carved features and colorful travertine deposits, among them a miniature Natural Bridge and Aladdin's Lamp. The far end of this passage has an elevation of about 1,230 feet, the lowest point in the caverns. It is about 12 feet lower than the floor in the center of Stonewall Jackson's Grotto.

At the entrance to Aladdin's Palace, the main passage leads upward into Stonewall Jackson's Grotto, a more spacious corridor which extends in a general southwest direction along the regional strike of the limestone. A portion of this room is also an unadorned channel. At places in the ceiling and along the left wall are etched features and circuitously carved channels indicative of stream erosion. The development of a row of columns under an enlarged crevice is well shown along the right side near Aladdin's Palace (Pl. 41A). Here also is found an interesting suspended balcony.

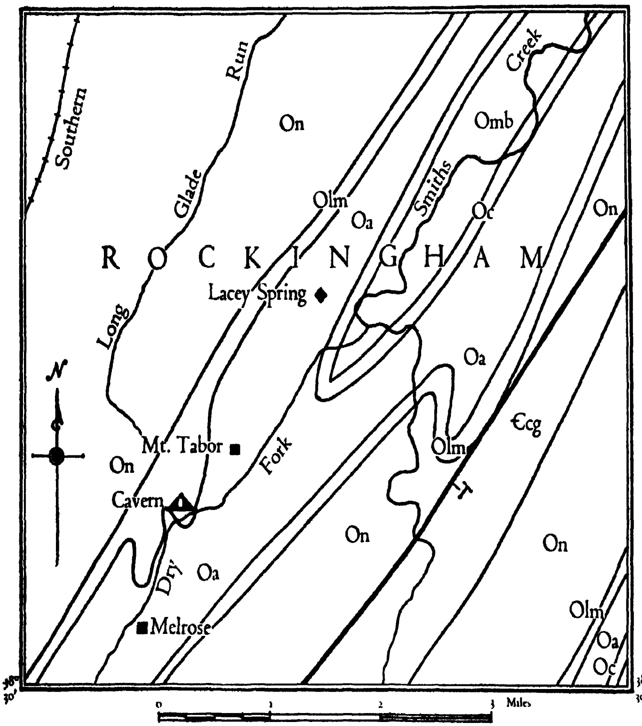
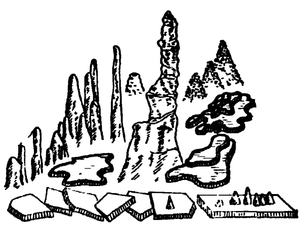


Figure 21.—Geologic sketch map of the environs of Virginia Caverns. (By Charles Butts.) €cg, Conococheague limestone; On, Nittany dolomite; Olm, Stones River (Mosheim and Lenoir) limestones; Oa, Athens formation; Oc, Chambersburg formation; Omb, Martinsburg formation. (Formations in northwest part of area are not shown.)

Cliff Dwellers' alcove. Recently a narrow passage has been opened whic leads southwestward for about 125 feet, past a sink-hole vent, to a ne room, about 40 feet long and 25 feet wide, which contains some ver attractive stalactites and stalagmites and two undercut benches. Shallo side channels, but partly explored, and which contain some interestin groups of small travertine deposits, extend northeast and southwest fror the end of this room.

Returning to the Hippodrome, a narrow circuitous passage lead about 70 feet northeast to the Underground Amphitheatre, an excep tionally beautiful underground scene. The blue color of the domed lim stone ceiling and walls greatly enhances the beauty of this veritabl fairyland, making it a fitting finale to one of the wonderlands of th nether world. From here one retraces his way to the entrance and throug the rock garden to the lodge.



CHAPTER IV

Undeveloped Caves

SMALL undeveloped caves and sink-holes are rather common in the extensive limestone belts in the Valley of Virginia and the Valley Ridges. The abundant sinks and suddenly disappearing streams throughout the Appalachian Valley in Virginia indicate that many underground drainage channels occur along soluble beds of limestone. It is probable that some of these underground channels are extensive. Considerable surface drainage at times enters the small caves and sink-holes.

The caves occur chiefly in bluffs or small limestone hills along or near the larger streams. Many of them are known only to local residents and have been but partly explored. Some of them have been known for many years[27] and others have been described recently.[28] Many of them contain interesting groups of travertine formations and a few of them springs or underground streams.

Interesting local stories of pioneer days in the Valley of Virginia tell of the use of many of the caves as retreats from marauding Indians. It is said that others were used as retreats for soldiers and local residents during the Revolutionary War and the War between the States. Deposits of cave earth or saltpeter were mined from several caves for the manufacture of gunpowder during the War between the States and some deposits are said to have been mined during the Revolutionary War.[29] Human and animal bones have been found in some of the caves.[30]

Brief descriptions and locations of many undeveloped caves, some examined by the writer and others reported to him, are on file in the offices of the Virginia Geological Survey, University, Virginia. This Survey will be glad to receive information about caves in the State. No doubt there are many caves known only to local residents or undiscovered in the Valley and Valley Ridges of Virginia. Some of the larger and more accessible caves may in time be developed and opened to the public.

Information about many of the known and reported undeveloped caves in Virginia is given by counties in Table 2.

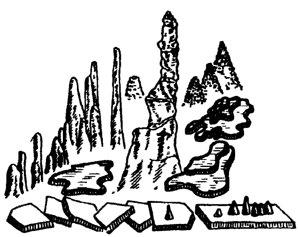


Table 2.—Undeveloped Caves in the Appalachian Valley in Virginia

County	Number of caves	Probable Geologic Horizon[a]	Extent
Alleghany	3	Helderberg limestone.	Small.
Augusta	8	Stones River, Beekmantown, Conococheague and Elbrook (?) limestones.	Small to several hundred feet.
Bath	14	Chiefly Helderberg limestone.	Small to several hundred feet.
Botetourt	2	Conococheague and Elbrook limestones.	([b])
Floyd	1	([b])	([b])
Frederick	2	Probably Helderberg, Chambersburg and Stones River limestones.	Several hundred feet.
Giles	2	Stones River and Helderberg (?) limestone.	Small.
Highland	3	Helderberg limestone.	Small.
Lee	1	([b])	([b])
Montgomery	2	Beekmantown, Conococheague and Elbrook (?) limestones.	Small.
Page	5	Chambersburg, Stones River, Beekmantown, Conococheague (?) and Elbrook (?) limestones.	Small.
Patrick	1	([b])	([b])
Pulaski	2	Probably Beekmantown, Conococheague and Elbrook limestones.	Small.

[a]See Table 3. Some of the horizons are approximations.

[b] Unknown.

Table 2.—Undeveloped Caves in the Appalachian Valley in Virginia (Continued)

County	Number of caves	Probable Geologic Horizon[a]	Extent
Roanoke	5	Conococheague and Elbrook limestones.	Mostly small.
Rockbridge	2	Chambersburg and Stones River limestones.	Small to extensive.
Rockingham	2	Stones River, Beekmantown and Conococheague (?) limestones.	Probably small.
Scott	Several	Beekmantown and Honaker limestones.	Small.
Shenandoah	3	Beekmantown and Conococheague limestones.	Small.
Smyth	3	Probably Copper Ridge and Honaker limestones.	Small.
Tazewell	6	Helderberg, Chambersburg, Stones River, Beekmantown and Conococheague (?) limestones.	Small to large.
Washington	3	Probably Helderberg, Beekmantown and Conococheague limestones.	Probably small.
Wise	Several	Probably Helderberg limestone.	Small.
Wythe	2	Probably Elbrook limestone or Shady dolomite.	Small.

[a]See Table 3. Some of the horizons are approximations.

[b]Unknown.

CHAPTER V

Characteristics of the Caverns

Excavation of Caverns

THE development of limestone caverns adorned with travertine has been divided into two distinct stages: A primary erosional stage during which the underground passages and channels are excavated, and a later depositional or replenishment stage, in which the previously created passages and rooms are adorned or partly filled with travertine deposits. According to Davis[31] the work of the first stage is 5 to 20 times greater than that of the second.

The excavation of limestone caverns is generally accredited to solution and corrasion by ground water circulating in crevices above the water table. Davis[32] calls this the "one-cycle" theory. The deposition of travertine is attributed to the later seepage of acidulated water into the abandoned passages above the water table after the water which excavated them had drained to lower levels or discharged into a nearby surface stream.

Davis proposes an alternative "two-cycle" theory for the origin of large caverns in dense horizontal limestones. The excavation of cavern channels is attributed to solution below the water table. The change from excavation by solution to depositional replenishment is ascribed to the sinking of the water table below the cavern level as a result "of regional uplift or other effective cause."[33]

The writer has not had an opportunity to determine the application of Davis' two-cycle theory to the origin of the Virginia caverns which are in folded limestones. For a detailed discussion of the rôle of

ground water in the development of caverns, the reader is referred to recent articles by Davis,[34] Lobeck,[35] and Weller.[36]

Channel Excavation

Caverns occur chiefly in limestone because ground water circulates along the beds and joints, and limestone is soluble in ground water. The limestones in the Valley are a few hundred to a thousand feet or more thick.

The general stratigraphic sequence of the rock formations in the Appalachian Valley in Virginia is shown in Table 3. The physiography of the region is described in Chapter VII and its geologic history is discussed in Chapter II.

The Appalachian Valley was once a great troughlike inland lowland in which, during Paleozoic time, were deposited tremendous thicknesses of limestone, sandstone and shale. In late Paleozoic time, during pronounced mountain-making movements, these sedimentary beds were highly folded, and in places broken by great thrust faults. Extensive parallel to sub-parallel folds and zones of crushed and broken rocks, termed overthrust fault blocks, were developed. By the erosion of the folds and fault blocks toward a common level, massive beds of limestone and dolomite have been exposed in northeast-southwest belts. The caverns occur in the more soluble or more folded beds where the movement of solvent waters through the limestones has been favored by bedding planes and joints.

Most limestone is composed largely of calcium carbonate, but some limestones in the Valley of Virginia contain considerable magnesium carbonate (Table 4). Limestone is dissolved slightly by pure water but is many times more soluble in water containing carbon dioxide or organic acids. Rain water absorbs carbon dioxide from the atmosphere

and also from decayed vegetation as it seeps downward through the soil, thereby forming weak carbonic acid which acts upon limestone to form the more soluble calcium bicarbonate.

Rain water seeps through the soil and subsoil into the underlying bedrock, and traveling as ground water moves downward along joints and beds in the limestone until it reaches the water table, or zone below which the rocks are filled with water, an impervious bed, such as shale, or well-defined zones of lateral crevices, or enlarged fissures generally along faults or along the strike of the limestone. Passageways along bedding planes, faults and joints are gradually enlarged by solution into more or less extensive underground conduits. Underground streams also enlarge the channels through wear on the roofs, walls and floors by sand, silt, pebbles and chert fragments from the cavern walls and washed in from the surface.

Solution and Stream Erosion

As the channels are at first developed largely by solution they are narrow, small, and very slowly excavated. Through the union of two small channels or several joint channels with a main bedding-plane channel, passages of sufficient size to permit a flow of water through them are slowly opened. As the flow of water thus increases, its solvent power becomes greater and channel enlargement continues. The channels are enlarged also through wear by transported particles of rock.

The enlargement and extension of cavern channels by stream erosion varies in different areas and in different portions of the same cavern. Subterranean stream erosion depends upon several variable factors, such as the size and extent of the channels, the resistance of the limestone, the volume and rate of flow of the water, and the nature and amount of sediment carried by the streams.

In one cavern or at places in the same cavern, solution may be greater, whereas, in other caverns or places, stream erosion may be more important in channel development.

Among the evidences of stream erosion in underground channels are: Smooth, rounded and polished walls and channels, winding passages, abandoned stream courses in the ceilings, furrows and potholes along walls and floors, undercut banks, overhanging balconies and ledges, pebble marks on walls and ceilings, fantastic bedrock projections from ceilings and walls, silt and sand-scoured travertine formations and deposits of sand, silt, and water-worn pebbles along channel floors. Examples of many of these features are found in the caverns of Virginia. They have been discussed in some detail under the individual caverns.

Development of Cavern Levels

Water is always seeking a lower level, the ultimate goal of all land waters being sea-level. In channels above the water table, ground water moves more rapidly than at or below this horizon, but faster at the water table than below it. The circulation of ground water in most caves is controlled directly by the elevation of the local master surface streams, because cavern drainage is chiefly through springs to these streams. After channels have been excavated, the underground streams may seek lower levels, either because lower courses have been opened along joints and bedding planes or the area has been gradually uplifted above sea-level, thus enabling the surface streams to cut their channels deeper. The old underground channels then become abandoned upper passageways, or a series of cavern rooms. As this process is repeated through long periods of time, cavern rooms and passages are formed at different levels. The wonderful caverns of Virginia apparently have been thus slowly excavated partly by solution and partly by stream erosion.

The fate of the waters that formed the many picturesque caverns presents an interesting problem. The caverns occur in low hills and the local surface streams are somewhat below the main cavern levels. The waters from the caverns reach the surface through springs, for example, at Massanutten Caverns, or through underground channels to surface streams.

Channel Characteristics

The caverns of Virginia are not as large as some in other states, but in characteristic features, variation in type, and in the richness, variety, and beauty of the "formations" which they contain, they invite world-wide comparison. Their size is determined chiefly by the character and structure of the rocks in which they occur.[37] As they are in rather narrow belts of steeply dipping limestone, they are not as extensive as some caverns excavated in horizontal limestones. The length of the main route over which visitors are conducted and approximate elevations of the caverns are given in Table 1.

Channels and Rooms

The developed caverns vary from simple, one-level channels excavated chiefly along the strike of the limestones to complex patterns of branching and intersecting passages and spacious chambers at several levels. Virginia Caverns are an example of the first type and Luray Caverns of the second type. Sketch maps of the individual caverns show in general that the main passages have been excavated chiefly along the strike of the limestones (Figs. 4 to 21). Complicated side passages and looped channels have been generally excavated along joints. Underground stream erosion and stream piracy also have probably aided in their excavation. Some features have been eroded in more soluble parts of the limestones.

Passages excavated along prominent joints and steeply inclined bedding planes are commonly high and narrow, whereas those along gently inclined bedding planes and in shattered zones in the limestone are generally lower and wider. Gradual enlargement of channels by solution, erosion by transported particles of rock, and undermining of side walls at different depths, alters the shape of the channels and may develop arched passages. A remarkable example of a Gothic arched passage, carved by water, is found in the entry passage to Virginia Caverns (Pl. 29). Connecting channels excavated between higher abandoned passages or sink-holes and lower channels are usually narrow and relatively deep. They are generally short and occur along prominent inclined or nearly vertical joints. Many were probably excavated, in part at least, by streams, and their narrowness is the result of downward erosion by rapidly moving water; for example, the narrow passages of Battlefield-Crystal Caverns. Travertine deposits are generally absent except at the convergence of the connecting channels with the main or lower passage.

Through continued or periodic enlargement of passages by solution and by stream erosion, some rooms and chambers of amazing proportions have been developed. They are generally along main passages at the convergence of two or more channels or in more soluble places in the limestone (Pls. 21 and 32).

Passages excavated at different levels are connected at first by narrow, vertical or oblique pipelike channels, generally along joints in the limestone. Where the beds of limestone are tilted or folded, as throughout the Valley of Virginia, the channels intersect the main or lower passages at steeply inclined angles. In the later excavation of the caverns, the connecting channels vary in shape and size from small, circular, steeply inclined pipelike channels (Pl. 33) to long, vertical rifts and

yawning underground chasms (Pl. 12). Through some of these deep underground gorges, gurgling waters may be heard far below.

The passageways through which visitors are conducted are dry and afford safe footing. All of the caverns contain damp spots where, during wet weather, drops of water trickle down the sides of huge stalactites or along flowstone on the wall. These wet spots generally occur near the surface, under surface depressions, and along well-defined joints. Frequently in passing a side room or channel, the splash of unseen water is heard. Small lakes, often of great charm, occur in several of the caverns and in two of them, Luray and Giant, small streams flow for a short distance along the main passages, their appearance being as unheralded as is their disappearance. The abundance and beauty of the stalactite groups above these lakes are shown in Plates 8B, 18A, and 23.

Erosion in Channels

The course of a stream may be influenced by greater solubility of the limestone, by a layer of impervious shale, or by fissures which lead to lower channels. Two underground streams flowing in nearly parallel channels at relatively short distances apart at the same or approximately the same level may unite by the solution and erosion of the limestone wall between them. Examples of the convergence of two or more stream channels are found in most of the caverns (Pls. 7A and 32).

Transported material and blocks of limestone from the cavern ceilings and walls are deposited in some rooms and along passages where tributary channels enter them. These deposits are generally covered with a coating of limy silt and flowstone (Pls. 10A and 32) and broken travertine formations sometimes accumulate at such places. They may be cemented together by the growth of secondary stalagmites or by other travertine deposits, as shown in Plate 13A. By the inwash of surface

material through sinks, abetted by the collapse of weakened roofs, streams obstruct or partly destroy the mysterious underground channels they have created. Waters from relatively recent rains and floods may have clogged or partly dammed some cavern channels. When these partly clogged channels are again flooded, they are sometimes reopened.

Massive rocks dislodged by solution and erosion are found in Giant and Shenandoah caverns. In Shenandoah Caverns huge slabs of limestone were loosened by water working along enlarged crevices believed to have been developed, in part at least, by fault movements. Large pendant columns and stalactites may be dislodged by the force of a large volume of water breaking suddenly into a channel. According to Hovey,[38] the Fallen Column, a massive stalactite in Luray Caverns, was broken in this manner. Several large stalagmites have since formed upon it.

Barren places are found in all of the caverns (Pl. 34A). They are due mainly to the absence of crevices in the limestone and hence the lack of ground-water seepage and deposition. Some barren ceilings have resulted from the fall of travertine-covered slabs.

Many of the rooms and alcoves along the main channels at the junction of tributary channels are circular or oval, particularly where the tributary discharged into the main passage at such an angle that a whirlpool was developed. At some places, circular and discoid channels have been carved in the ceilings (Pl. 34B) and fantastic designs have been etched in the ceilings and on the walls. Some of these features may have been formed in part by slow solution or by the gentle, ripple-like movements of standing bodies of water. Other peculiar pendant forms are thought to have been formed largely by stream erosion. Examples are found in most of the caverns but are more evident in Endless Caverns (Pl. 35). An interesting group of erosional features interspersed with

Plate 32. A room at the junction of two underground channels in Grand Caverns. Note the flowstone-covered terraces and undercut banks along the left wall, and the three shields suspended from the ceiling.

Plate 33. A nearly vertical pipelike connecting channel near the Spectre Column in Luray Caverns. Through it considerable water from older upper passages reached Dante's Inferno. (Copyrighted by Luray Caverns Corp.)

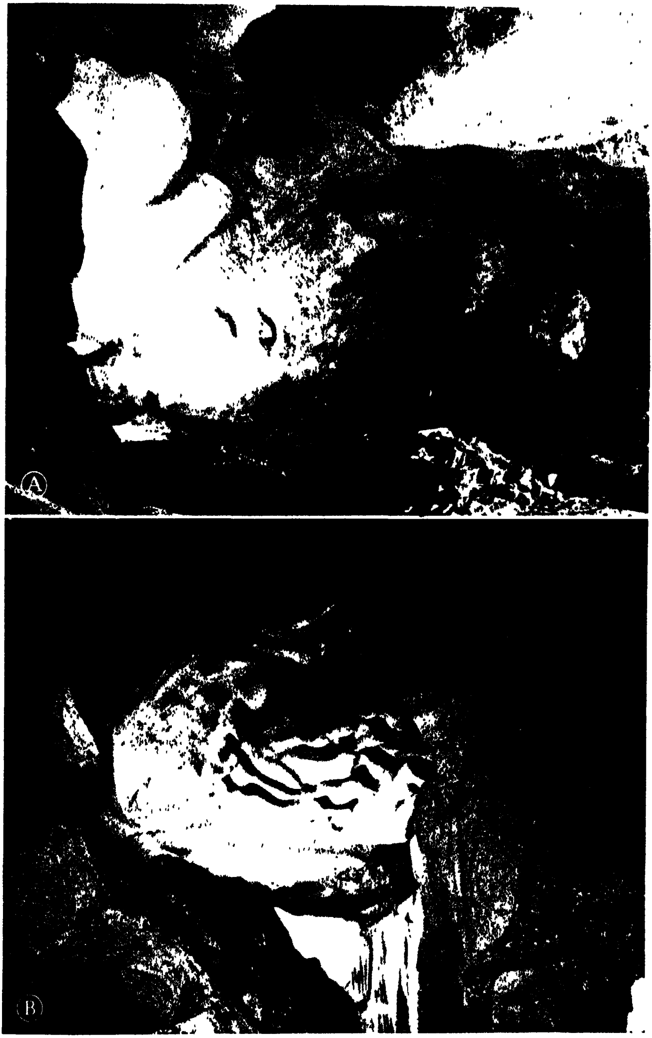


Plate 34. A, A barren corridor in limestone in Virginia Caverns. Flowstone-covered terraces flank the walk in this winding passage.
B, An abandoned circular channel in the ceiling of Endless Caverns. One of many interesting erosional features in these caverns.

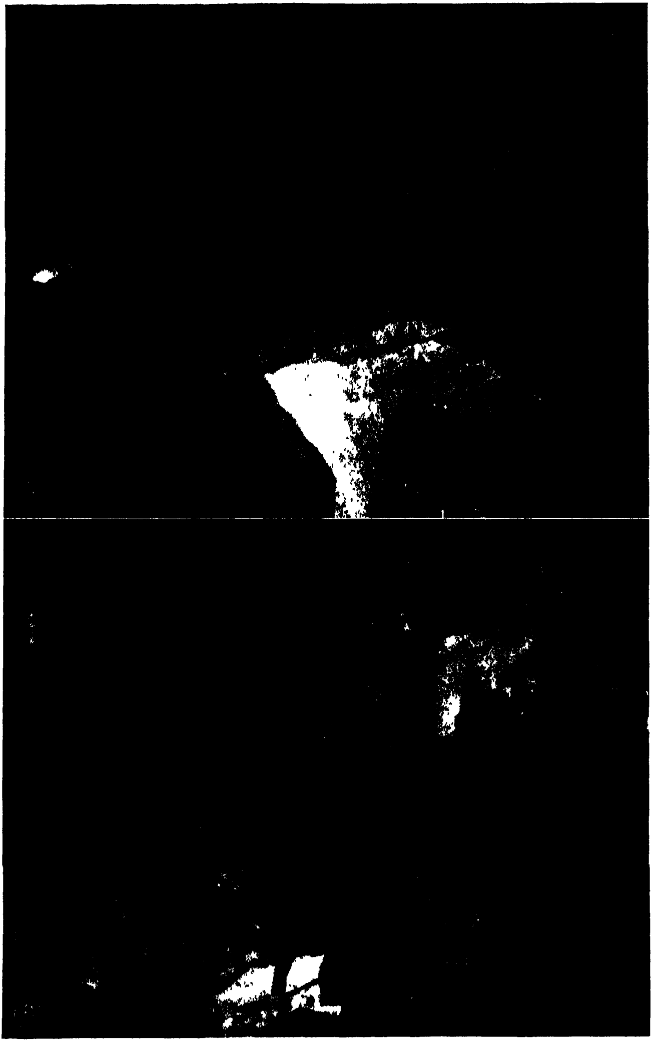


Plate 35. A, An etched ceiling in Endless Caverns. The Angel's Wing in the Marine Corridor, showing significant erosion of limestone.

B, Erosional pendants in Endless Caverns. These forms resembling draperies were carved by water from the limestone ceiling.

actites, stalagmites and flowstone is to be seen in Aladdin's Palace Massanutten Caverns (Pl. 22).

There occur in portions of Endless, Grand and Massanutten cav-s smoothly polished, rounded or almond-shaped projections of estone which were probably formed, in part at least, by the scour-action of silt and pebbles. In parts of Endless and Virginia Caverns walls and ceilings of barren channels are smooth and rounded, hav- a more or less circular outline suggestive of stream erosion. In por-1s of Battlefield-Crystal Caverns the walls and floor are distinctly tted with marks made by pebbles in whirlpools at the convergence :wo streams. In another part of these caverns pebbles are found in clay and silt on the floor. Hovey[39] has noted the occurrence of /el-cut domes in Luray Caverns.

Nestlike holes, ripple-like and furrow-like troughs and stream-carved ressions also occur along the walls, in the ceilings and on the floors nany rooms and corridors, particularly in the circular or well-like ms and alcoves in Virginia, Dixie, Endless, Giant, Grand, Luray Massanutten caverns.

The thickness and profusion of travertine deposits on the walls and ings and the stream-deposited material on the floors of most of caverns prevent in many places a detailed study of the original chan-. Positive evidence of mechanical erosion is thus often obscured oncealed but probable evidences as mentioned above are found here there in most of the caverns, especially in Endless, Battlefield-Crystal Virginia. Such features strongly suggest that stream erosion has, in 'es and at times, played a prominent part in the excavation of the :rns of Virginia.

Benches and Shelves

During the movement of waters charged with calcium bicarbonate

through underground channels, thin films of calcium carbonate are deposited on the floors, which, in time, may attain a thickness similar to that of the sheet and flowstone deposits described under "Travertine Deposits." As the waters recede from parts of the old channels or abandon them for newer ones, these deposits dry out and crystallize into hard, protective coatings. Where streams have cut through these deposits and the fresh limestone beneath them has been dissolved, portions of the recrystallized layer are left as undercut benches or ledges. During repeated intervals of down-cutting and widening of the main channel, shelves or ledges have been formed at successively lower levels in most of the caverns (Pls. 6 and 36A).

Terraces

By the deposition of a slimelike coating of flowstone over silt or clayey deposits in rooms or channels, terraces are developed. Accumulations of broken travertine formations, fallen limestone blocks and inwashed material also are covered with similar coatings of flowstone resulting in terraces. In places a series of them has been built at successively higher levels, as in Giant and Grand caverns (Pls. 10A and 32). Terraces of variable extent and thickness occur in most of the caverns.

Travertine Deposits

As long as the circulation of acidulated water continues, channels are enlarged and an extensive cavern system is excavated. Uplift of the cavern area or sinking of the water table causes the channels to be abandoned. The further enlargement of these passages by solution and stream erosion ceases and deposition of travertine may commence in them. Davis[40] states that the change from solutional excavation to depositional replenishment is brought about when the ground water "which

had completely filled the cavern during the progress of its excavation, is drained away and its place is taken by ground air, the presence of which provokes evaporation of percolating vadose water and escape of carbon dioxide from it, and thus compels it to deposit calcite and form dripstones on the cavern roof and floor." In a cavern system comprising channels and rooms at several levels, solution may be active in the lower channels while deposition is taking place in the upper levels.

Of most interest to visitors are the many attractive deposits of travertine which adorn the caverns of Virginia. They vary greatly in size, shape, form, texture and profusion. Some are translucent, many are tinted or streaked in bright colors, and some are resplendent with crystal brilliance.[41] Crystals of calcite and veinlike stringers or bands of crystallized calcite also are found.

Origin

The deposits of travertine, transforming plain and barren caves into veritable fairylands of bizarre and colorful forms, are composed of calcium carbonate that was dissolved from the limestone by percolating ground water. Common, drab limestone has thus been changed into travertine of great beauty. Deposition has been along the ceilings and walls as the water seeped through crevices and bedding planes in the limestone. It is caused mainly by evaporation of water in contact with air in the cave and by loss of solvent carbon dioxide from the water. The variation in shape, form and abundance of the deposits is due largely to differences in physical and chemical conditions obtaining at the place and time the travertine was deposited.

Types

Because of their profusion, beauty and interesting origin, the varied

types of travertine deposits are separately described. More than 20 varieties, such as stalactites, stalagmites, flowstone, dripstone, draperies and shields are found in the caverns of Virginia. The more prominent varieties are shown in Figure 22. The most common and conspicuous deposits are stalactites, which hang like icicles from ceilings and ledges, stalagmites, which grow upward from the cavern floors, and flowstone, which coats the side walls.

Stalactites vary greatly in size and shape, ranging from single dainty, graceful forms a few inches long, such as are profusely developed in Massanutten Caverns, to groups of long and thick draperies and columns of dripstone and flowstone, such as are well shown in Luray Caverns (Pls. 21 and 37A). They are commonly formed along cracks in the ceiling of a cavern, through which the percolating ground water seeps, and under projecting ledges from which the water drips.

Ground water containing calcium bicarbonate in solution, seeping slowly through small crevices, reaches the ceiling of a cavern where it collects and hangs in drops until they are large and heavy enough to fall. As the drop grows and breaks away, some of the water evaporates and a small circular film of calcium carbonate is deposited at the spot from which the drop fell. Repetition of this process builds up a slender, hollow, icicle-like stalactite (Pls. 8B, 36B, and Fig. 22) through which the water trickles and drops from the lower end. These single stalactites are graceful, generally delicate, white or even transparent and of uniform thickness. They are rarely more than 18 to 20 inches long and occur profusely in lengths of 8 to 10 inches. When the end of the tube becomes clogged by suspended vegetable or mineral matter, the water trickles down the side of the stalactite, increasing its thickness and adding variety to its form. If the stalactite grows freely on all sides, it will become an inverted tapering cone, as shown in Figure 22. Some

develop into pipelike or conical forms several feet long (Pl. 41B) Single forms unite to produce twinned forms and groups of intergrown pendants.

The variety in form and size and the profusion of stalactites are shown in Plates 21, 23 and 37A. Stalactites along joints are shown in Plates 10A and 30, and along bedding planes in Plate 13B. A secondary growth of small stalactites on older stalactites and draperies is rather common.

Helictites are peculiar branchlike stalactitic forms which are found in most of the caverns but are more abundant in parts of Shenandoah, Luray and Massanutten caverns (Pl. 37B and Fig. 22). These strange, crooked multitwisted forms seem to result from impurities in the water trickling along fluted draperies and stalactites from which they grow like mistletoe. It is probable that changes in temperature and in direction, volume and humidity of air currents influence the growth and development of these and of some of the other curiously shaped deposits.

Knotty nodular forms, grapelike clusters on ceilings and walls (Pl. 9 and Fig. 22) and stucco-like coatings on stalactites and stalagmites (Pl. 24B) are thought to be due to condensation without dripping of waters containing impurities, or to crystallization of calcium carbonate around impurities. These forms are more prominent in Massanutten, Luray and Shenandoah caverns. Spongelike and coral-like growths on ceilings and walls covered with flowstone (Pl. 25) are probably formed in the same manner.

Peculiar bulbous enlargements or beet-shaped and potato-shaped stalactitic growths occur in Endless and Massanutten caverns. In places two or more of these bulbs appear on the same slender stalactite (Pls. 9 and 37A, and Fig. 22).

Stalagmites grow slowly upward as the water charged with calca-

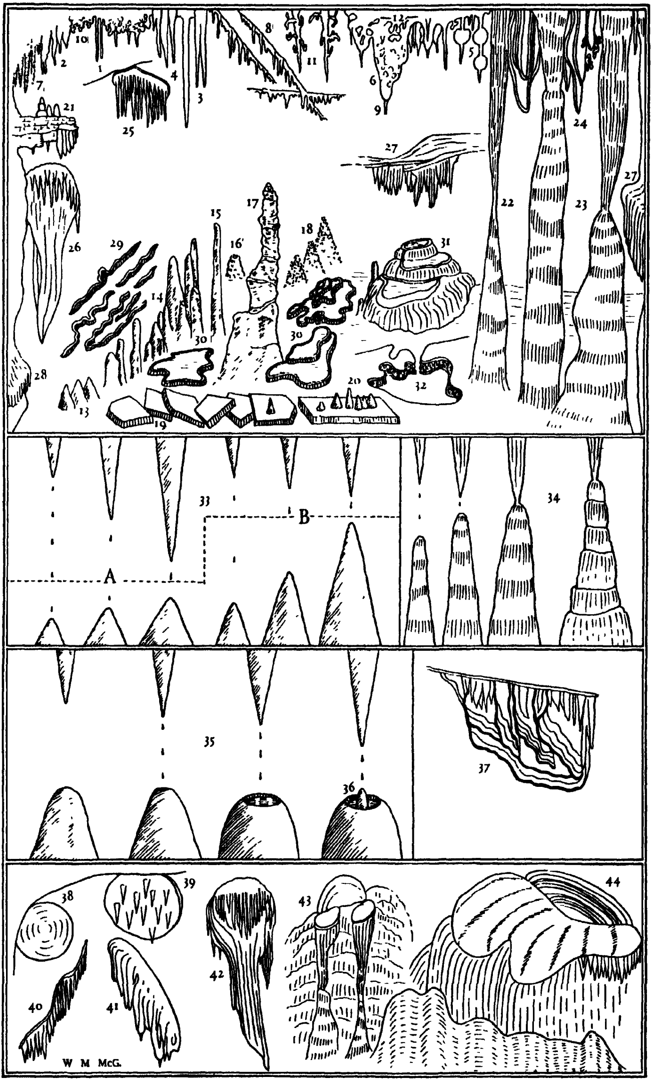


Figure 22.—Composite sketch of cave deposits

Composite Sketch of Cave Deposits

EXPLANATION

1. Single, slender, straw-shaped stalactite.
2. Cone-shaped stalactite.
3. Twin or double stalactites.
4. Long, slender, tapering stalactite.
5. Odd-shaped, beet-, potato-, or orange-like stalactite forms.
6. Nodular grapelike encrustations on stalactite.
7. Pebble-like coatings on stalactites.
8. Rows of stalactites along joints in ceiling.
9. Secondary stalactites on older travertine forms.
10. Coral-like or sponge-shaped forms.
11. Helictites.
12. Variety of stalactitic forms.
13. Small, single, cone-shaped stalagmites.
14. Round-topped stalagmites.
15. Slender postlike stalagmites.
16. Cup-topped or wasp-nest stalagmite.
17. Step-growth, terraced stalagmite.
18. Pebble-like coatings on stalagmites.
19. Broken limestone slabs.
20. Small stalagmites on broken limestone blocks.
21. Stalagmites on benches and shelves.
22. Slender columns tapering to point at union of stalactite and stalagmite.
23. Columns formed through intergrowth of stalactites and stalagmites.
24. Streamer-like and fin-shaped draperies.
25. Shield spiked with stalactites.
26. Drapery-adorned shield.
27. Shelves and ledges on wall adorned with stalactite-drapery forms.
28. Flowstone coated shelf or bench with undercut bank.
29. Corrugated basin-rims.
30. Lily pads or corrugated basins.
31. Troughlike travertine basins.
32. Concretionary forms embedded in cavern floor.
33. Comparison in size between stalactites and stalagmites:
    A. Slow drip, stalactite grows faster.
    B. Rapid drip, stalagmite grows faster.
34. Development of columns through intergrowth of stalactite and stalagmite.
35. Showing development of cup-topped or wasp-nest stalagmites.
36. Secondary stalagmite in top of older cup-topped stalagmite.
37. Bacon-strip and curtain draperies.
38. Barren shield affixed to wall in inclined position.
39. Stalactite-spiked shield suspended from ceiling at an angle.
40. Shield, adorned with stalactite draperies, formed along inclined bedding plane in the limestone.
41. Drapery enshrouded shield suspended from wall at an angle.
42. Stalactite and drapery enshrouded shield.
43. Drapery-stalagmite columns, shields and terraced flowstone deposit.
44. Massive flowstone cascade.

reous material drops upon the cavern floor and evaporates. They vary greatly in size, shape and diversity of forms. Rapid evaporation and a small volume of water develop slender stalagmites (Pl. 36B and Fig. 22), whereas a larger flow of water and slower evaporation build larger, cone-like forms having broader bases (Pl. 26 and Fig. 22). Flat-topped and shallow saucer-shaped forms result from the deposition of calcium carbonate around the rims of small puddles. The alignment of stalagmites beneath stalactites, under joints, masses of dripstone and ledges is shown in Plates 17 and 41. Many attractive clusters of small stalagmites are found on the tops of broken columns or other formations (Pl. 13A). Others occur also on benches and shelves (Pl. 36A).

Through repeated intervals of growth, steplike pillars or terraced stalagmitic columns are formed (Pl. 38 and Fig. 22). Stalagmites resembling ancient castle watch towers, picturesque minarets or Indian totem poles, many of matchless beauty and gigantic proportions, occur in most of the caverns. A most attractive array of these spectacular terraced towers is found in Giant's Hall in Luray Caverns (Pl. 18B). Many tall pillars and leaning towers are blanketed or partially veiled with artistic draperies.

Dome-shaped stalagmites, representing completed growth, are of rather common occurrence in many of the caverns (Pl. 39A and Fig. 22). Renewed drip from a stalactite upon the dome will form a cuplike or saucer-like depression (Pl. 39B). This type of stalagmite which sometimes resembles a hornets' nest is perhaps best developed in Endless, Shenandoah and Luray caverns but occurs also in Massanutten and Giant caverns. A small, secondary stalagmite is rarely built up in the center of the eroded dome of the older stalagmite (Fig. 22).

Clusters of nodular grapelike and potato-like masses are formed in places on the cavern floors and in alcoves and side chambers, as the

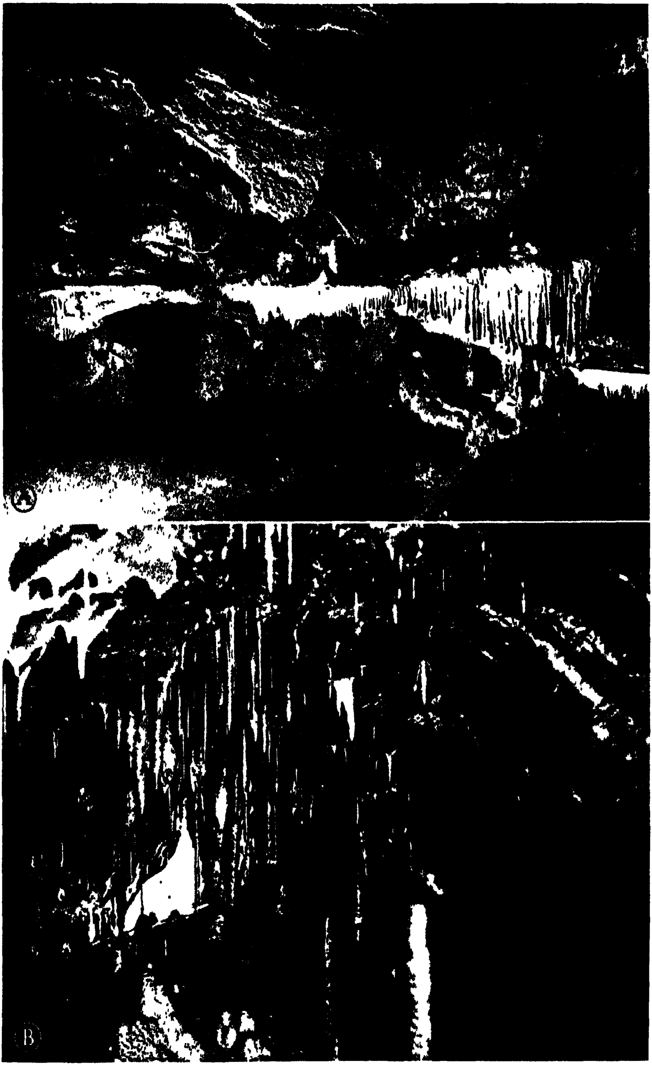


Plate 36. A, A flowstone bench in Grand Caverns. A remnant of a former floor of the Ball Room. A small stalagmite rises from the bench.
B, Single tubular stalactites and slender, postlike stalagmites in

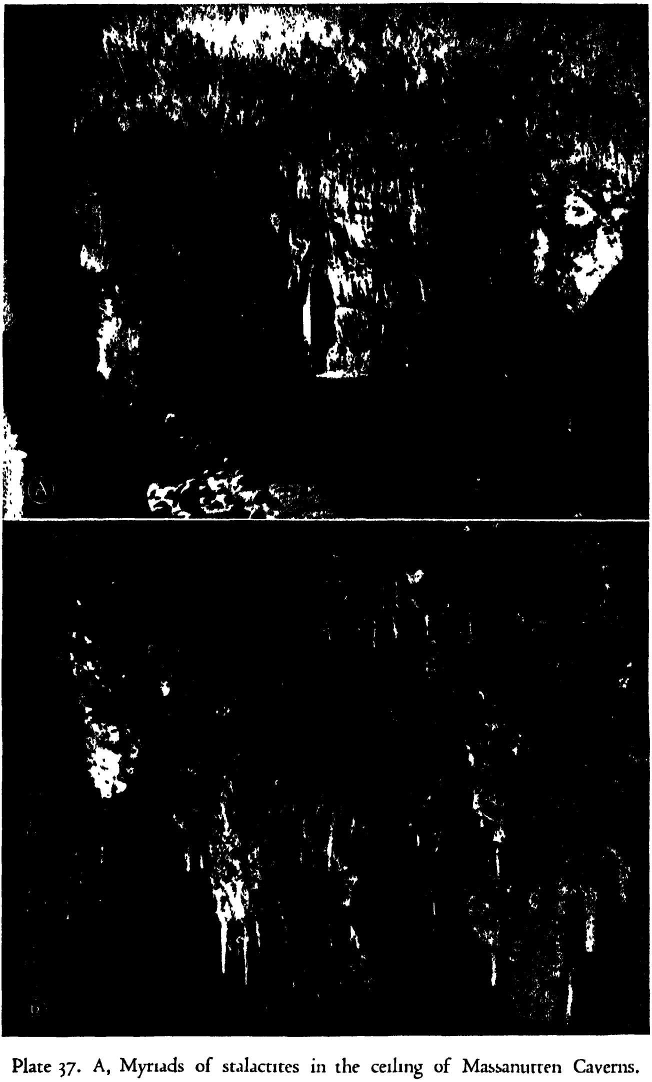


Plate 37. A, Myriads of stalactites in the ceiling of Massanutten Caverns. Note the odd, bulbous and pebbly coated varieties shown here.
B, Helictites in Shenandoah Caverns. They are the curious branching forms projecting from the stalactites above Rainbow Lake.

Vegetable Garden in Luray Caverns (Pl. 40). These odd forms are probably developed by the crystallization of calcium carbonate as concretions around cores of mineral matter and impurities in the evaporating water.

The variations in size of stalactites and stalagmites are shown in Plates 14, 36B, 41B and 42, and Figure 22. Their rate of growth depends upon several variable factors, chiefly the volume of water, its concentration, rate of drip, rate of evaporation and changing chemical conditions. In general, if the water drops slowly the stalactite will grow faster and be larger, whereas if the drip is rapid the stalagmite will be larger.

Estimates of the rate of growth of stalactites and stalagmites have been made in many caves in various parts of the world. Attempts also have been made to estimate, from measurements of "growing formations" and observations on their present rate of growth, the age of certain massive stalactites and stalagmites and of the caves in which they occur. The results have varied greatly because of the different conditions under which they were obtained. It has been estimated that from a few years to several score years are required for the deposition of a cubic inch of stalactitic material.[42]

Columns or pillars are formed through the union of stalactites and stalagmites. They vary greatly in size, shape and occurrence but are most commonly developed in rows under joints in the ceiling (Pl. 41A and Fig. 22). They are rather conspicuous features of each of the caverns of Virginia. Small, slender, graceful symmetrical columns frequently tapering to pencil-like tubes at the point of union of the stalactite and stalagmite, adorn the side rooms, galleries and benches along the main passages of Endless, Dixie and other caverns (Pl. 41B).

In many of the larger rooms, columns of gigantic size constrict the

passageways and some entrances have been almost blocked by massive columns, such as are shown in Plate 42. They occur generally under enlarged joints and connecting channels. Natural gateways of artistic design are formed by some columns, for example, the spectacular natural Portal in Virginia Caverns (Pl. 30). Beautifully fluted or reeded and jointed effects are produced on many columns by mantles of dripstone and flowstone (Pls. 20 and 42). Columns and complex pillars of amazing size and shape, resembling giant trees, prehistoric monsters or some man-made monument are abundant. They result generally from the intergrowth of groups of stalagmites with clusters of stalactites, draperies and masses of flowstone. Spectacular massive intergrown forms, images and monuments are found in most of the caverns, particularly in Luray, Shenandoah, Endless and Grand caverns.

Columns may be broken when struck forcibly by large fragments of rock carried by flood waters. If, during a flooding of old channels, heavy blocks of limestone are lodged against columns or stalagmites and press against them for a long time bent columns may result. A column probably bent and cracked in this manner is found in Massanutten Caverns (Pl. 24B). Cracked, broken and recemented columns, many of which have resulted from the undermining of the base of the column by percolating water, are found throughout the caverns. Cracked and broken columns are recemented by the deposition of travertine in the cracks. Where columns have thus been reunited, ribbon-like welts, which resemble growth rings on trees, belt them. Broken and recemented columns are found in each of the caverns. A portion of a welt around a recemented column is shown on Plate 7A.

Draperies are ribbon-like or streamer-like stalactites of rare beauty (Pls. 17, 42 and 44A, and Fig. 22). They are formed by waters charged with calcium bicarbonate trickling over and under ledges and shelves

in tiny rills, similar to the action of rain drops on roofs, instead of dropping from a single point. The several varieties of draperies in the caverns of Virginia have distinct individual charms. They vary from single ribbon-like and banner-like streamers to clusters of massive, flag-draped pendants, groups of gracefully folded, artistically banded, giant blankets and daintily ruffled curtains. Many are translucent and are beautifully tinted with bands of yellow, orange, brown and red. Others of snow-white brilliance are found in secluded niches along winding passages or shine conspicuously among large groups of allied stalactitic forms. Fascinating draperies are numerous in each of the caverns but are probably more profusely developed in Luray, Shenandoah and Grand caverns (Pls. 16, 17, 26 and 42).

Draperies result also from the union of parallel stalactites in rows along joints in the ceilings and also under ledges or shelves. The ruffled or wavelike form which they generally assume is believed to originate in part as explained above. It is possible that air currents may influence the growth of some of these forms.

An interesting variety of fin-shaped drapery is found in Luray Caverns where a row of parallel forms, averaging about 1 foot in length, occurs along the edge of a bench thickly coated with flowstone (Pl. 43). Because of their striking resemblance to fish, tiers of these forms are frequently termed "cave market" or "fish market" and the forms themselves are more appropriately called "rockfish." Several attractive rows of these rockfish occur in Grand Caverns (Pl. 12).

Another realistic form which bears the appropriate title of "cave bacon" or "bacon strips" is shown on Plate 44A. It is probably more abundant in Shenandoah Caverns, though similar forms are to be seen in the other caverns. The bottom and outer edge of many strips of cave bacon, and of other larger types of drapery, are often characteris-

tically etched in a toothlike or burnt-bacon manner. These crackled or notched edges probably result from the drying out and cracking of the ends of the dripstone deposits. The bacon strips are generally streaked in brown and red in a most realistic manner. The coloring of these and of many other travertine deposits is due to mineral and organic matter in the waters from which they were deposited. The variation in color and parallel banding of the tinted forms has been caused chiefly by iron, manganese, organic salts and discolored clay which the waters contained at different times.

It is probable that some of the ruffled ribbon and bacon types, and certain of the sheet draperies or partition draperies, such as are well developed in Grand Caverns, were originally formed by the deposition of calcium carbonate in sheet or vein deposits. The waters seeped so slowly through crevices in the limestone that instead of enlarging them by solution, deposition occurred in them. Deposits of this type could be formed in narrow spaces between beds of limestone and veinlike fissures in the limestone. As the main channel was enlarged and broadened by continual solution and erosion, abetted by the sloughing of fragments of limestone from the walls and ceilings, the sheetlike layers of travertine would be exposed.

Travertine sheets occur in Grand Caverns, in several places comprising a portion of the walls of corridors and rooms and forming in two places natural sheet-rock partitions between adjoining rooms. These sheets occur in crevices between beds of limestone which are nearly vertical. Numerous sloping shelves and portions of eroded inclined ledges, possibly formed in a similar manner, are also found in these caverns.

Shields are one of the most enchanting and universally admired types of travertine deposits. They are most prominently developed in

Grand Caverns but occur also in Endless and Luray. For symmetry, sheer beauty and artistic appeal, the brilliant, snow-white shields are not excelled by any other type of travertine formation. They vary in size, position in which they occur and manner of secondary adornment but have a striking similarity of form. Many are circular forms, apparently riveted to the ceiling in a horizontal position, from which hang large clusters of fluted spear-shaped stalactites or picturesque groups of stalactite draperies of crystal brilliance. Others spiked with secondary flowstone and dripstone of great beauty hang suspended at apparently precarious angles from the ceilings, overhead galleries and high ledges in the large rooms and passageways (Pl. 44B and Fig. 22). Many broken stalactite-adorned shields are lodged against groups of columns in the larger chambers and against projections on the walls. Several groups of broken shields, long since firmly enmeshed amid a mass of dislodged travertine, occur in Grand Caverns (Pl. 13A). In Grand and Endless caverns are found broken forms of peculiar interest, where sharp, fluted, spearlike, stalactite-encrusted shields have fallen from the ceiling and now stand like tables above the floor into which the supporting stalactites were deeply thrust (Pl. 45A).

Several scarf-draped shields of great beauty are found in Grand Caverns, probably the most beautiful being the Bridal Veil in the Bridal Chamber (Pl. 16). The beautiful drapery adorning and enshrouding it was formed after the shield became affixed to the wall. The calla lily or stone lily formations in Grand Caverns are other interesting and beautiful drapery-adorned shields (Pl. 15).

Two possible origins of these shields are here suggested: The concentric deposition of travertine, as in the formation of stalactites, in thin, disclike masses around small crevices or wet spots on the ceiling, or the breaking of exposed portions of shelves, benches and sheetlike

deposits of flowstone into circular or discoidal forms. The characteristic shape of the shields if formed by the first method is probably due in part to the local saturation of the seeping waters with dissolved calcium bicarbonate and to the effect of air currents in directing the growth. Seepage over the surface and along the edge of the growing deposit may also influence the final shape. In the undermining and breaking of travertine sheets and ledges it is possible that some of the fragments broke along lines of weakness. This origin of some of the shields by fracturing is suggested by the position in which many of them are found and their resemblance to similar sheetlike forms along exposed bedding planes, for example, the Oyster Shell in the Shell Room in Grand Caverns (Pls. 13B and 15).

Flowstone designates here diverse types of travertine deposits which have not been previously discussed and which characteristically adorn the walls. The walls of corridors and rooms, shelves and benches along the walls, and some of the older and more massive columns and stalactites are commonly covered with peculiar travertine deposits. Many of the typical forms resemble stalactites, draperies and allied drip forms with which they are intermixed and intergrown. Complex and contrasting intergrowths occur at one spot, whereas a slight distance beyond the walls are thickly covered by a different but locally characteristic type of deposit.

Flowstone is formed by waters flowing over the walls and into lower levels from higher levels or from intersecting and feeder channels. It is derived from the deposition of calcium carbonate by trickling and flowing waters saturated with calcium bicarbonate, and the rapid evaporation of shallow, flowing sheets of water, or a combination of these and other variable conditions.

Prominent among the flowstone forms are blanket-like wall and

drapery coatings, such as characterize Shenandoah and Luray caverns (Pls. 17 and 25). Many of these wall blankets of variable thickness and extent are adorned with secondary stalactites, stalagmites and draperies, some of considerable size. Several of the high-vaulted passages in Shenandoah Caverns are thickly and profusely blanketed with flowstone which is, in places, ornately embellished and richly fluted by later drapery and stalactitic deposits (Pl. 25).

The walls and fringing stalagmites are frequently covered with pebble-like or rough stucco-like encrustations, as in Massanutten (Pl. 24B), Shenandoah (Pl. 25) and Luray caverns (Pl. 42). These curious growths are thought to be due to sediment in the waters, variation in the rate of evaporation, and variable conditions existing during their deposition. In places barnacle-like or grapelike growths hang from the flowstone-sheeted walls.

Flowstone masses of exceptional size have been formed at the convergence of streams, as in Grand (Pl. 32), Endless (Pl. 7A) and Luray caverns (Pl. 19). At such places, large barriers or dams have been formed by the deposition of massive piles of rock fragments. When these rock piles were later covered with flowstone, terraces resulted. According to Hovey,[43] the outlets from many of the rooms or corridors in Luray Caverns were thus probably dammed for a long time.

Among the more striking flowstone deposits are the solidified cascades, crystallized waterfalls and marble fountains formed at the intersection of inclined tributary channels with the main channel. They afford some idea of the volume of water that reached the main passage through tributary channels. These petrified waterfalls occur in all of the caverns but are probably more abundant in Endless Caverns (Pl. 8A).

Corrugated basins are formed where falling water from growing stalactites and draperies and some of the water trickling over the floor

collects in small pools or basins on the uneven cavern floor. As the water becomes saturated with calcium bicarbonate and overflows, deposition takes place at the edge of the basin, thus building up gradually wave-like corrugated rims (Fig. 22). A series of these corrugated or ruffled travertine-rimmed pools may be developed at successive heights over the irregular floor. Their height is generally 2 to 3 inches. These ruffled basin rims are found in most of the caverns but are most evident in Dixie, Endless, Giant and Luray caverns (Pls. 45B and 46A).

Where conditions are favorable for a considerable time for the building of these basin rims, bowls are formed, as in Luray Caverns. The rims of the large and deep pools grow inward as the bowl is built up, producing a curious form (Fig. 22). The bowls in Luray Caverns are about 8 inches deep.

Other Deposits

Calcite crystals of much beauty are found locally in the caverns of Virginia, usually as fillings in small lens-shaped cavities in the walls. Two interesting, small, crystal-lined cavities, resembling miniature "jewel boxes," in Massanutten Caverns are pointed out by the guides. These crystals differ in origin from the travertine deposits in that they were most probably formed while the cavern channels were filled with water charged with calcium carbonate. Here and there throughout the other caverns are noted small clusters of brilliant fernlike calcite crystals.

Feathery and needle-like crystals of aragonite, in picturesque groups or clusters, have been noted in Luray and Endless caverns and in several of the undeveloped caves.

Clusters of gypsum crystals and encrustations of gypsum along the walls and ceiling have been reported from Endless Caverns and a few of the undeveloped caves.

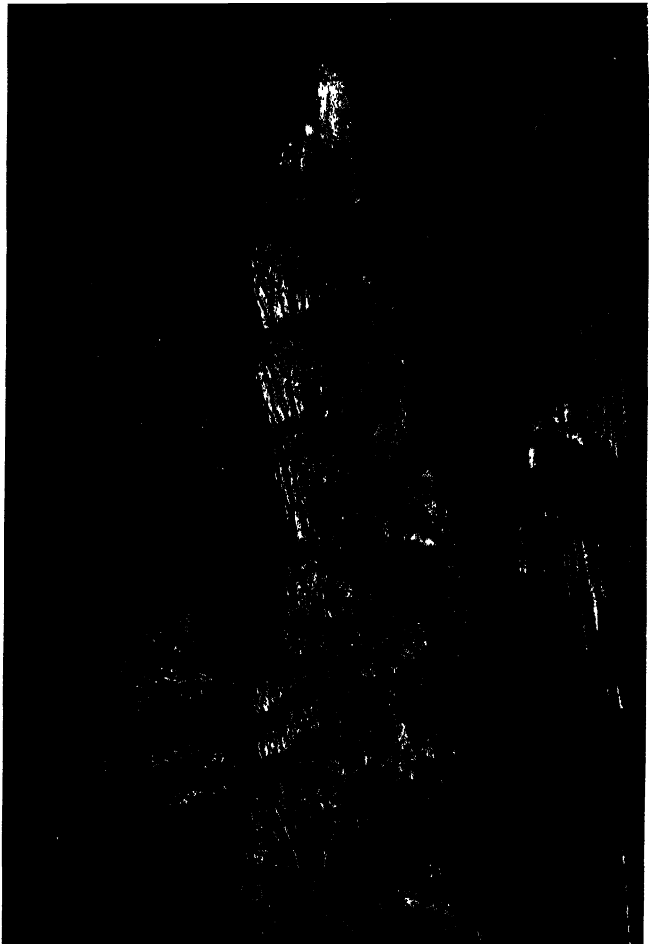


Plate 38. Steplike stalagmitic column in Luray Caverns. The Empress Column, formed by intermittent drip and growth. The Column is about 30 feet high. (Copyrighted by Luray Caverns Corp.)

Plate 39. A, Dome-shaped pedestal stalagmites along Sacred River in Luray Caverns. (Copyrighted by Luray Caverns Corp.)
B, Cup-topped stalagmites in Endless Caverns. Many resemble petrified hornets' nests. They are from 1 to 2 feet in height.

Plate 40. Clusters of nodular growths in the Vegetable Garden in Luray Caverns. The stalagmites and floor of this alcove are encrusted with pebble-like concretionary forms. (Copyrighted by Luray Caverns Corp.)

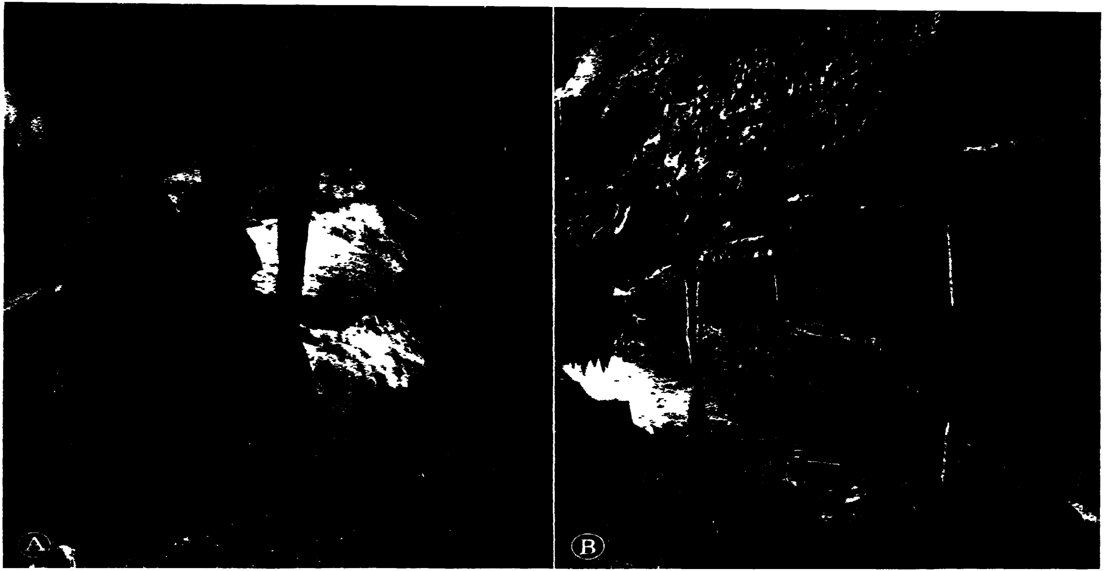


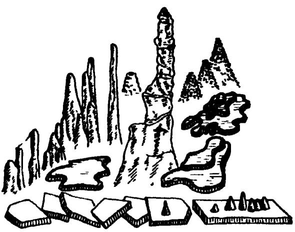
Plate 41. A, Columns and stalagmites aligned along a joint in Virginia Caverns. Note eroded channels in rear wall. B, Slender columns in Endless Caverns. Note the graceful, tapered pencil-point union of the stalactite-stalagmite columns guarding the entrance to Fairyland and the bulbous stalactites on the ceiling.

Ribbon-like veins of calcite are found in the walls and ceilings of several of the caverns. They were formed by the deposition of calcium carbonate in narrow crevices, through which the percolating water seeped too slowly to enlarge the crevices by solution. A series of almost evenly spaced parallel veins, averaging from 1½ to 2½ inches thick, rib the ceiling and the walls of the Ball Room in Battlefield-Crystal Caverns. They appear to have been set in the limestone by some master architect. These calcite ribs are portions of veins deposited in crevices at right angles to the strike of the limestone.

In portions of Luray, Battlefield-Crystal and Endless caverns, round nodular concretions, about the size of marbles and small pebbles, are embedded in the floors (Pl. 46B). They were probably formed by the crystallization of calcium carbonate around impurities in the evaporating water. When broken they are found to be hollow and show radial structure. A few cave-pearls, rounded and polished concretions of calcite, sometimes considered as gems, have been noted in some of the caves in Virginia. Interesting examples are the small calcite eggs found in the Bird's Nest in Luray Caverns. These cave-pearls were formed under water in shallow basins or pools and were polished and rounded by rubbing against each other in the agitated water.

Channels through which silty waters slowly flowed and rooms which were filled with water for a long time contain deposits of silt and clay, in places several feet thick, which vary in composition from place to place. Some of this material is surface sediment washed in through sink-holes or surface feeder channels, but much of it is insoluble material derived from the dissolved limestone and carried as suspended matter in the subterranean streams. In parts of Grand, Endless and Luray caverns considerable thickness of silt and clay have been deposited along the main passages and in several of the larger rooms.

Deposits of earthy material derived from the decomposition of undissolved portions of the limestone occur in many of the caves in Virginia. Nitrates have apparently at certain times been obtained from some of this cave earth.[44] The Elfin Ramble and the passage from it to Dream Lake in Luray Caverns contain a thickness of several feet of chalklike material deposited by the water which for a long time occupied this portion of the caverns.



CHAPTER VI

Character of Bedrock

THE rocks in the Valley of Virginia are principally limestone, dolomite and shale which occur in relatively extensive northeast-southwest belts. In sharp contrast is the west slope of the Blue Ridge consisting mainly of resistant sandstone and quartzite. The prominent Valley Ridges to the west are composed chiefly of highly resistant sandstone with some limestone and shale. The geologic formations in the order of their age, the oldest being at the bottom, and their characteristics are shown in Table 3. Their distribution is shown on the geologic map of Virginia[45] and the new map of the Valley.[46]

Three of the developed caverns are in Upper Cambrian and six are in Ordovician limestone. Dixie is in Elbrook limestone (Cambrian), Grand and Shenandoah are in Conococheague limestone (Upper Cambrian or Ozarkian), Luray is in the Beekmantown group (Lower Ordovician or Canadian), Endless, Giant, Massanutten and Virginia (formerly called Blue Grottoes) are in the Stones River group (Ordovician), and Battlefield-Crystal is in Chambersburg limestone (Ordovician).

The entrance to each of the caverns and the geological formations exposed in its vicinity are shown on the geologic sketch maps accompanying the descriptions of the individual caverns. Some salient features of the caverns are given in Table 1.

Lithology

The Elbrook limestone in the vicinity of Dixie Caverns is composed largely of thinly bedded blue-gray compact limestone with in-

Table 3.—Geologic Formations in the Appalachian Valley in Virginia[a]

System		Formation or group[b]	Thickness[c] (Feet)	Characteristics
Mississippian.		Pennington shale.	1,000±	Red and purple sandy shale with beds of sandstone.
		Newman limestone.[d]	1,000–3,600	Thick beds of blue to gray limestone, brown to reddish sandstone, and sandy shale.
	Pocono	Maccrady formation.	50–75	Red and green shale and sandstone.
		Price formation.	250–1,700	Thickly bedded, coarse-grained sandstone, with beds of shale and conglomerate.
Devonian.		Catskill formation.	1,500–1,800	Red sandstone and shale.
		Chemung formation.	2,000±	Chiefly shale and sandstone, with some conglomerate.
		Brallier shale.	1,000–4,000	Olive-green sandy shale and thin sandstone.
		Romney shale.	300–1,500	Mainly dark-gray to black shale.
		Oriskany sandstone.	0–150	Friable gray sandstone.
		Helderberg group.	50–300	Limestone with cherty and sandy beds.

[a] Formations above the Mississippian system and some formations in southwestern Virginia, which do not occur throughout the Valley, are not included in this table. For these formations see Geologic map of Virginia, Virginia Geological Survey, 1928; also, Geologic map of the Appalachian Valley in Virginia, Virginia Geol. Survey Bull. 42, 1933.

[b] Classification based on recent work by Charles Butts.

[c] Thicknesses of the formations vary considerably through the length and breadth of the Appalachian Valley in Virginia. Those given here are provisional but are probably close approximations.

[d] The Newman limestone is approximately equivalent to beds of Glen Dean (Cove Creek), Gasper, Ste. Genevieve, St. Louis and Warsaw age.

Table 3.—Geologic Formations in the Appalachian Valley in Virginia[a] (Continued)

System	Formation or group[b]	Thickness[c] (Feet)	Characteristics
Silurian.	Cayuga group.	50–500	Limestone, sandstone and shale.
	Clinton group.	100–500	Mainly ferruginous sandstone and shale.
	Clinch sandstone.	50–500	Hard, quartzitic sandstone.
Ordovician.	Juniata formation.	200–500	Red shale and sandstone.
	Martinsburg formation.	1,500–3,000	Gray calcareous shale and limestone.
	Chambersburg formation.	50–400	Limestone and calcareous shale.
	Moccasin formation.	400–1,000[e]	Reddish and gray impure limestone and shale.
	Lowville limestone.	300–1,000[e]	Blue to dove-colored limestone.
	Athens formation.	50–5,000	Dark-gray to black shale and limestone.
	Holston limestone.	10–300	Coarse-grained gray, pure limestone and marble.

[a] Formations above the Mississippian system and some formations in southwestern Virginia, which do not occur throughout the Valley, are not included in this table. For these formations see Geologic map of Virginia, Virginia Geological Survey, 1928; also, Geologic map of the Appalachian Valley in Virginia, Virginia Geol. Survey Bull. 42, 1933.

[b] Classification based on recent work by Charles Butts.

[c] Thicknesses of the formations vary considerably through the length and breadth of the Appalachian Valley in Virginia. Those given here are provisional but are probably close approximations.

[e] Largely equivalent facies.

Table 3.—Geologic Formations in the Appalachian Valley in Virginia[a] (Continued)

System			Formation or group[b]	Thickness[c] (Feet)	Characteristics
Ordovician. (Continued.)		Stones River	Lenoir limestone.	10–100	Dark-colored, knotty, cherty, impure limestone.
		Stones River	Mosheim limestone.	10–100	Bluish-gray, pure limestone.
	Canadian	Beekmantown	Bellefonte dolomite.	50–1,500	Bluish-gray, cherty magnesian limestone and dolomite.
	Canadian	Beekmantown	Nittany dolomite.	500–1,200	
	Canadian	Beekmantown	Stonehenge limestone.	100±	
Cambrian.	Ozarkian		Conococheague limestone.	1,600–2,000	Chiefly bluish-gray magnesian limestone.
	Ozarkian		Copper Ridge dolomite.[f]	1,200	Mainly gray magnesian limestone and dolomite.
			Elbrook limestone.[g]	1,400–3,000	Mainly limestone and limy shale.

[a] Formations above the Mississippian system and some formations in southwestern Virginia, which do not occur throughout the Valley, are not included in this table. For these formations see Geologic map of Virginia, Virginia Geological Survey, 1928; also, Geologic map of the Appalachian Valley in Virginia, Virginia Geol. Survey Bull. 42, 1933.

[b] Classification based on recent work by Charles Butts.

[c] Thicknesses of the formations vary considerably through the length and breadth of the Appalachian Valley in Virginia. Those given here are provisional but are probably close approximations.

[f] The Copper Ridge dolomite, which occurs in the western belts of the Appalachian Valley province, may be contemporaneous with the Conococheague limestone, which occurs only in the eastern belts.

[g] The Elbrook limestone is approximately equivalent to the Honaker limestone in southwestern Virginia, but may also include the equivalent of the Nolichucky shale (Butts).

Table 3.—Geologic Formations in the Appalachian Valley in Virginia[a]
(Continued)

System	Formation or group[b]		Thickness[c] (Feet)	Characteristics
Cambrian. (Continued.)	Rome formation.		1,000–2,000	Purple and red sandy shale with some beds of sandstone and limestone.
	Shady dolomite.		1,500–2,000	Blue to gray dolomite with beds of limestone and sandy shale.
	Chilhowee	Erwin quartzite.	500–1,200	Mainly quartzite with some shale.
		Hampton shale.	500–1,000	Dark-colored shale with thin beds of sandstone.
		Unicoi sandstone.	2,000±	Sandstone and quartzite with some shale and conglomerate.

[a] Formations above the Mississippian system and some formations in southwestern Virginia, which do not occur throughout the Valley, are not included in this table. For these formations see Geologic map of Virginia, Virginia Geological Survey, 1928; also, Geologic map of the Appalachian Valley in Virginia, Virginia Geol. Survey Bull. 42, 1933.

[b] Classification based on recent work by Charles Butts.

[c] Thicknesses of the formations vary considerably through the length and breadth of the Appalachian Valley in Virginia. Those given here are provisional but are probably close approximations.

terbedded gray and brown shale. Thicker beds of dove-colored to blue limestone comprise the upper part of the formation, whereas the lower portion is more shaly. The major part of Dixie Caverns is in the thicker bedded blue-gray limestone. The composition of the Elbrook limestone as determined from representative samples from the caverns is shown in Table 4. The thickness of this limestone has been found to be 1,000 to 1,600 feet in Roanoke County.[47] Sink-holes are rather common in the Elbrook limestone and many springs issue from it.

The Conococheague limestone consists essentially of irregularly in-

terbedded gray to blue limestone and dolomite with some characteristic beds of sandstone in the lower part. It contains a few thin beds of clay and some chert. The thickness ranges from 1,600 to 2,000 feet. Grand and Shenandoah caverns are in the Conococheague limestone.

The greater part of Grand Caverns is in thickly bedded dark-gray and bluish-gray limestone. Its composition is shown in Table 4. Thin veins and specks of calcite are in places conspicuous in the darker limestone. Madison's Cave, the entrance to which is about 1,500 feet southwest of the entrance to Grand Caverns, is in this limestone. Numerous sink-holes occur along the crest and southwest slope of Cave Hill.

The exposures near the entrance to Shenandoah Caverns are chiefly thinly bedded gray to dove-colored limestone. The developed portions of Shenandoah Caverns are chiefly in dark blue-gray limestone whose composition is given in Table 4. Thick beds of blue magnesian limestone containing clayey layers are exposed along the road northwest of the Caverns Inn.

The Beekmantown group comprises light-gray to blue, cherty, generally fine-grained, magnesian limestone and dolomite. The thickness of this group ranges from 800 to 2,000 feet. The composition of representative samples of limestone from Luray Caverns is shown in Table 4. Surface exposures are usually grayish-blue or dove-colored and yield a grayish-brown to dark-brown cherty soil.

Cave Hill, about a mile west of Luray, in which Luray Caverns occur, and similar ridges flanking Massanutten Mountain on the east are in a belt of cherty Beekmantown limestone. The entrance to Luray Caverns is in a thickly bedded dove-colored limestone which breaks with a concohidal fracture. In some of the lower passages thin beds of fine-grained, compact, siliceous, gray limestone occur between thicker beds of semicrystalline to dense dove-colored limestone. Ruffner's Cave on

Plate 42. Massive fluted columns and draperies in Luray Caverns. Clusters of small round-topped stalagmitic pedestals rise from the flowstone terraces. (Copyrighted by Luray Caverns Corp.)

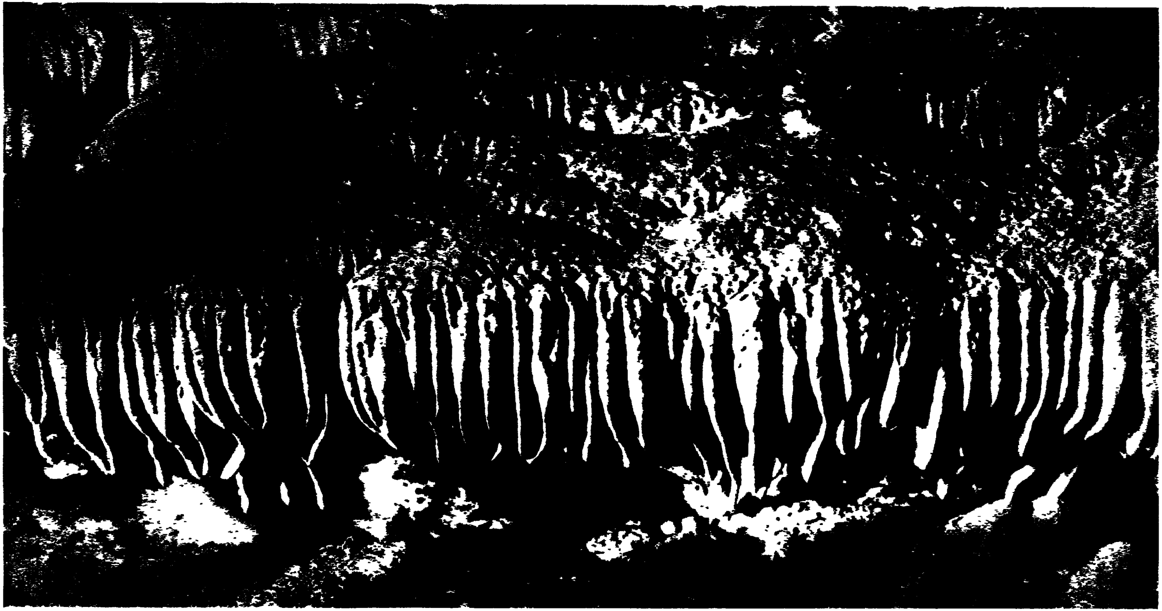


Plate 43. Rockfish draperies in Luray Caverns. A string of petrified rockfish fringe a projecting ledge in the Fish

Plate 44. A, Bacon-strip draperies in Shenandoah Caverns. Realistic bands of brown and red enhance the appeal of these transparent draperies. B, Inclined stalactite-adorned shields in Grand Caverns. Note the position of the shields along bedding planes in the limestone.

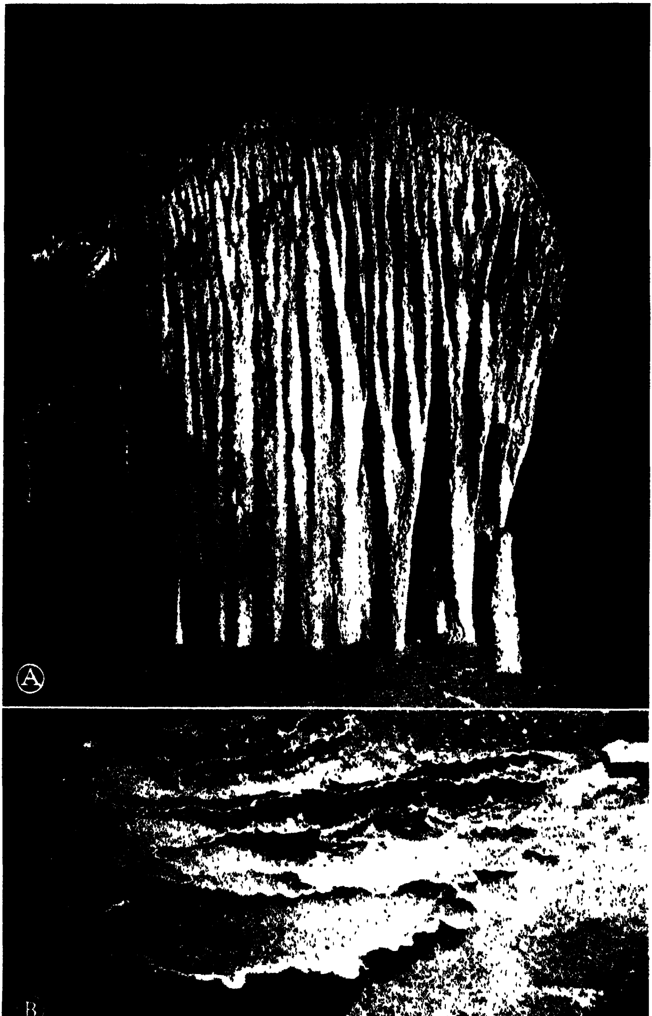


Plate 45. A, A giant shield in Endless Caverns. This shield spiked with spear-shaped stalactites broke from the ceiling countless years ago.
B, Basin-rim corrugations in Endless Caverns. Interesting remnants of former basined pools on the floor of the Marine Corridor.

the northwest slope of Cave Hill and many sink-holes occur in the Beekmantown in the vicinity of Luray Caverns.

The Stones River group in Shenandoah Valley includes the Mosheim and Lenoir limestones. The Mosheim is a fine-grained, dove-colored, pure limestone. The Lenoir is a dark-gray, coarse-grained, cherty, impure limestone. The thickness of the Stones River group ranges from 30 to 200 feet. Endless, Giant, Massanutten and Virginia caverns are in Stones River limestones. The composition of representative samples from each of these caverns is given in Table 4.

Outcrops of weathered gray to dove-colored limestone are prominent along the slopes of Wolf Creek Mountain in the vicinity of Giant Caverns. The lower developed part of the caverns occurs in a massive, fine-grained, gray to dove-colored limestone. In the larger part of the caverns a thickly bedded dark blue-gray limestone overlies the dove-colored member. Both members contain irregular chert nodules as much as several inches thick. The dark-gray limestone is in places semicrystalline to crystalline and has been termed a marble.

A good exposure of the limestone in which the greater part of Massanutten Caverns occurs is found in an abandoned quarry at the southwest end of Cave Hill, about 150 feet from the entrance to the caverns. Here the Mosheim is a massive, fine-grained, dove-colored limestone containing thin veins of calcite. At places in the caverns are exposures of dark-gray semicrystalline limestone impregnated with specks of calcite.

The surface and underground exposures at Virginia Caverns are very similar to those at Massanutten Caverns. Virginia Caverns are in a massive, compact, fine-grained, dove-colored limestone containing small veins and specks of calcite.

Exposures of light-gray, dove-colored and darker limestone occur

on the summit and slopes of Cavern Hill at Endless Caverns. These caverns are in gray and dove-colored limestone similar to that at Massanutten Caverns, the entrance being in the same belt. Exposures of dark-gray, cherty, impure limestone are found at places, noticeably in the lower passages.

The Chambersburg formation comprises relatively pure and clayey limestone and dolomite varying from light-gray to dark-gray. The gray and dove-colored beds are fine-grained and thin, whereas the darker magnesian limestones are relatively thickly bedded, are fine- to coarse-grained, and contain in places veins and specks of calcite. The thickness of the Chambersburg formation ranges from 50 to 400 feet.

Good exposures are found on either side of the highway near the entrance to Battlefield-Crystal Caverns. The larger part of these caverns is in the purer dark-gray to dove-colored, fine-grained limestone. In places in the caverns, shaly, carbonaceous, cherty limestone is interbedded with the light-colored beds. The limestone contains in places considerable chert and it is thought that many of the small nestlike holes along the walls may have been formed, in part at least, by the removal of chert nodules. The composition of the limestone is given in Table 4.

Structure

The dominant structural features of the Valley of Virginia may be characterized as a series of relatively extensive parallel northeast-southwest folds broken by several faults.[48] Numerous small folds occur along the flanks of the major folds and cross folds occur locally.

In the northwestern part of the Valley the folds are relatively broad and open, but toward the southeast they are sharper and relatively close. Where closely folded some have been broken by great thrust faults. In many places great fault blocks have been shoved far to the northwest

Table 4.—Partial Analyses of Limestones from the Caverns of Virginia
(J. H. Yoe, M. C. Goldberg and Leopold Sender, Analysts.)

	1	2	3	4	5	6	7	8	9	10	11	12	13
Al_2O_3 } Fe_2O_3	2.58	0.42	3.80	0.90	2.12	0.66	0.57	3.48	0.46	2.26	2.44	1.42	1.14
$CaCO_3$	84.21	98.36	89.35	92.14	75.09	98.51	94.99	76.50	89.81	68.96	64.13	84.47	64.45
$MgCO_3$	0.15	0.57	2.65	0.19	8.34	0.38	0.21	13.09	0.53	5.34	1.84	1.53	30.10
Insoluble residue	14.00	0.47	4.41	6.38	14.05	0.83	3.96	9.07	9.79	22.31	30.79	13.53	4.20
	100.94	99.82	100.21	99.61	99.60	100.38	99.73	102.14	100.59	98.87	99.20	100.95	99.89

1. Chambersburg formation, Battlefield-Crystal Caverns; gray, fine- to coarse-grained, shaly limestone.
2. Stones River limestone, Endless Caverns; light-gray, fine-grained, compact limestone.
3. Stones River limestone, Giant Caverns; dove-colored to dark-gray, compact, thickly bedded limestone; semicrystalline in places.
4. Stones River limestone, Massanutten Caverns; dove-colored, fine-grained, massive limestone.
5. Stones River limestone, Massanutten Caverns; dark-gray, coarse-grained, semicrystalline limestone.
6. Stones River limestone, Virginia Caverns; light-gray, fine-grained, compact limestone, similar to No. 2.
7. Stones River limestone, Virginia Caverns; bluish-gray, fine-grained, compact limestone.
8. Beekmantown limestone, Luray Caverns; bluish-gray, thickly bedded, magnesian limestone; cherty and siliceous in places.
9. Conococheague limestone, Shenandoah Caverns; bluish-gray to dark-gray, fine- to coarse-grained, clayey and siliceous limestone.
10. Conococheague limestone, Grand Caverns; dark-gray, coarse-grained, dense to semicrystalline limestone.
11. Conococheague limestone, Grand Caverns; dove-colored, fine-grained, even-textured limestone.
12. Conococheague limestone, Grand Caverns; bluish-gray, fine-grained, compact, cherty limestone.
13. Elbrook limestone, Dixie Caverns; gray to dove-colored, magnesian limestone; cherty and siliceous in places.

over the underlying rocks (Figs. 1 and 23). Several major faults, because of their extent and relation to structural conditions, have been termed master faults. One of them is the Blue Ridge thrust fault which extends for many miles along the west slope of the Blue Ridge. Another is the Pulaski overthrust which extends from Tennessee northeastward for more than 200 miles.[49]

The surface features are closely related to the structure of the region. The mountains are composed of the more resistant sandstone and quartzite along the flanks of the folds, whereas the valleys are underlain by the weaker shale or more soluble limestone.

The structure of the formations has also influenced the surface drainage and the circulation of ground water. It appears that the location and excavation of most of the caverns are intimately related to, if not largely determined by, the local structure. The accompanying sketch maps and geologic maps of the developed caverns show that the caverns occur in the areas of folded rocks and that in most of them the major passages extend along the strike of the formations. Most of the main passages may, therefore, be termed strike channels.

In the vicinity of Battlefield-Crystal Caverns, outcrops of the Chambersburg formation swing eastward for a short distance, due to local deformation, and then continue northeastward along the southeast slope of an anticline towards Middletown (Fig. 5). On top of Cave Hill near the entrance and in the caverns the limestone strikes generally N. 60° E. and dips 12°-14° SE. The Vista, the largest corridor in the caverns, trends S. 28°-30° E. along a dip joint in the limestone (Fig. 4). The Ball Room, the Hall of Masonry and the longer passages are strike channels. The shorter connecting and side passages are mainly along joints transverse to the strike of the limestone. Joints are well shown in several of the outcrops near

the entrance to the caverns and at a few places along the main underground tour.

The Elbrook limestone has been severely folded and faulted in the area surrounding Dixie Caverns. The northwest boundary of the Elbrook is the Salem overthrust fault along the southeast slope of Fort Lewis Mountain[50] (Fig. 7). In the vicinity of the caverns the strike is N. 70°-73° E. and the dip is 30°-34° SE. Several local variations in strike and dip occur. In the Curio Room the strike of the limestone is N. 80° E. (Fig. 6). The longer passages are generally along strike joints, with the side channels following transverse joints. The Auditorium is a good example of a large chamber excavated on three different levels at the intersection of strike and transverse joints. Most of the developed part of Dixie Caverns is along the strike of the limestone.

The entrance to Endless Caverns is in Stones River (Mosheim) limestone on the north end of an anticlinal hill which trends nearly north (Fig. 9). The strike of the limestone is generally N. 60°-65° E., but near the caverns and locally underground, the strike is N. 35°-45° E. and the dip is 14°-20° SE. Most of the developed part of Endless Caverns consists of corridors and chambers extending along prominent north-south joints produced in part by faulting, with a number of intersecting passages extending southeastward and northwestward along joints transverse to the strike of the limestone (Fig. 8). Joints and the development of cavern channels along enlarged joints are probably more evident in places in Endless than in the other caverns of Virginia.

The formations surrounding Giant Caverns have been extensively folded and in places faulted (Fig. 11). The caverns occur in a pitching anticline which extends through the northeast end of Wolf Creek Mountain. Around Giant Caverns the Stones River limestone strikes

N. 60°-70° E. and has an average dip of 20°-35° SE. The developed portion of the caverns consists of a series of large chambers and connecting passages extending northeastward along the strike (Fig. 10). The passages have been excavated on two main levels. A few side channels extend southeastward down the dip along enlarged transverse joints. Joints are well developed in the massive limestone in Entrance Hall and Giant's Corridor.

The Conococheague limestone around Grand Caverns has been greatly folded. Cave Hill is on the flank of an anticline which strikes N. 18°-20° E. (Fig. 13). The beds dip 86° SE. near the entrance and in the caverns the dip ranges from 65° to 85° SE. In the Ball Room and in the Senate Chamber dips of 82°-86° SE. occur. Along the longer passage between the Senate Chamber and the Shell Room the limestone dips 80°-85° NW. The longer passages occur along the strike, but a few passages are transverse to it. The Ball Room and the passage which connects that room with Cathedral Hall trend N. 70°-75° W. (Fig. 12). Joints are well developed at the surface and in the caverns.

Luray Caverns are in coarsely plicated Beekmantown limestone on the southeastern limb of the Massanutten Mountain syncline. At the entrance the limestone appears to be nearly horizontal (Fig. 15). The prevailing strike of the limestone is N. 45° E. and the dip is 25°-35° SE. The larger chambers and corridors are aligned along strike joints. Intersecting and looped cross channels and rooms, some of considerable size, occur along enlarged joints which extend southeastward and northwestward from the main strike channels (Fig. 14).

Massanutten Caverns are in Stones River (Mosheim and Lenoir) limestone in a small anticlinal ridge on the northwest limb of the Massanutten Mountain syncline. The hill trends N. 45°-50° E. along the strike of the limestone (Fig. 17). The beds dip 60°-68° SE. The

longer and larger passages and rooms extend northeastward along the strike. Side passages occur along joints that extend nearly at right angles to the strike (Fig. 16). Joints are well shown in some walls and in the old quarry at the southwest end of Cave Hill.

Massanutten and Endless Caverns are in the same belt of Mosheim and Lenoir limestone. They are about 14 miles apart on the southeast limb of the anticline that extends from Keezletown northeastward toward New Market.

Shenandoah Caverns are in a hill on an anticline of Conococheague limestone which trends N. 20°-30° E. (Fig. 19). The limestone has been folded and in places faulted in the caverns. Along Entrance Hall the limestone strikes N. 45° E. and dips 45°-55° SE. The long passage from the Grotto of the Gods to the Glacial Room and the Balanced Rock is along a fault which trends about N. 48° W. The Glacial Room, Snyder's Hall and the passage to Rainbow Lake extend N. 20°-25° E. along the strike (Fig. 18). Limestone along these passages dips 36°-38° SE. Joints are well shown along the main and in some of the shorter passages.

Shenandoah Caverns are on the crest of the large anticline that extends northeastward through Mt. Jackson. Battlefield-Crystal and Virginia caverns occur on the southeast limb of this major anticline that extends from the vicinity of Harrisonburg northeastward beyond Winchester.[46]

Virginia Caverns are in a small hill in a narrow belt of Stones River (Mosheim and Lenoir) limestone on the southeast limb of the anticline that extends from the vicinity of Harrisonburg northeastward and west of Lacey Springs and New Market to Mt. Jackson (Fig. 21). They appear to be located on a small transverse fold. Near the caverns the prevailing strike of the Stones River (Mosheim and Lenoir) limestone is N. 45°-55° E. and the dip is 12°-16° SE. Variations in strike noted at

places throughout the caverns are due to local folds. The major developed portion of the caverns consists principally of passages and larger halls connected longitudinally along pronounced strike joints. The main passage from the end of the caverns to Stonewall Jackson's Grotto extends along the prevailing strike. From the entrance to the Grotto to the caverns' entrance, the main channel trends N. 75°-85° E. along a winding course (Fig. 20). This eastward trend follows a local change in the strike of the limestone, probably resulting in part from cross folding. Several side passages and a few cross channels extend southeastward at right angles to the strike. Joints are seen at places in the caverns.

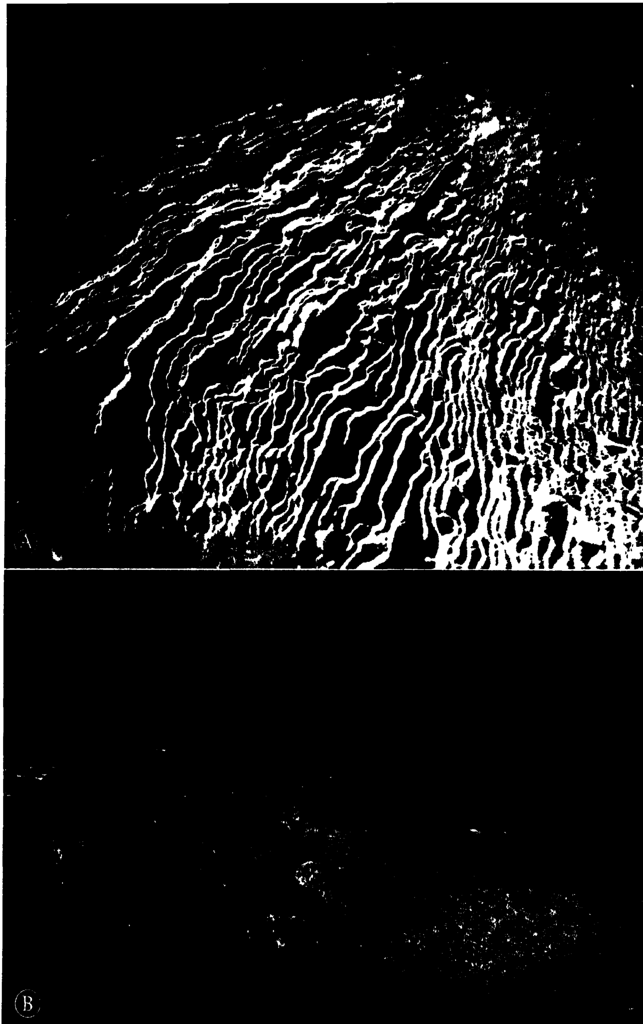


Plate 46. A, Radiating ribbon-like corrugations on the floor of the Marine Corridor in Endless Caverns. They appear to be in motion.

B, Concretionary deposits embedded in the floor of the Bronze Room in Endless Caverns. The nodules are from 1 to 2 inches thick.

Plate 47. Shenandoah Valley from the summit of Massanutten Mountain northeast of Woodstock. Looking west from the U. S. Forest Service observation tower across several of the picturesque horseshoe bends or entrenched meanders of the North Fork of Shenandoah River. (Photograph by H. Morrison, Jr.)

CHAPTER VII

Physiography of the Appalachian Valley

Appalachian Valley

THE Appalachian Valley[51] in Virginia is a part of the extensive geologic and geographic province which extends from southeastern Canada southwestward to central Alabama. This province has been designated also the Valley and Ridge province of the Appalachian Highlands. It consists of two distinct parts: An eastern lowland or series of broad, elongate valleys called the Great Valley, in Virginia commonly known as the Valley of Virginia, and a western area of relatively narrow, linear mountain ridges and deep intermontane valleys. The western section is called the Valley Ridges but is often referred to locally as the Allegheny Ridges or Mountains. The Appalachian Valley and its subdivisions in Virginia are shown in Figure 23. They have been described also by Stose[52] and Wright.[53]

Valley of Virginia

Between the lofty Blue Ridge on the east and the Valley Ridges on the west, the picturesque Valley of Virginia extends from the Potomac on the north southwestward for more than 360 miles to Tennessee. It is a beautiful tract of rolling country averaging 20 to 30 miles in width. It rises from 300 feet above sea-level at Harpers Ferry, on the Potomac, to about 2,500 feet in places in southwestern Virginia. The summits of the Blue Ridge tower 2,000 to 3,000 feet above the

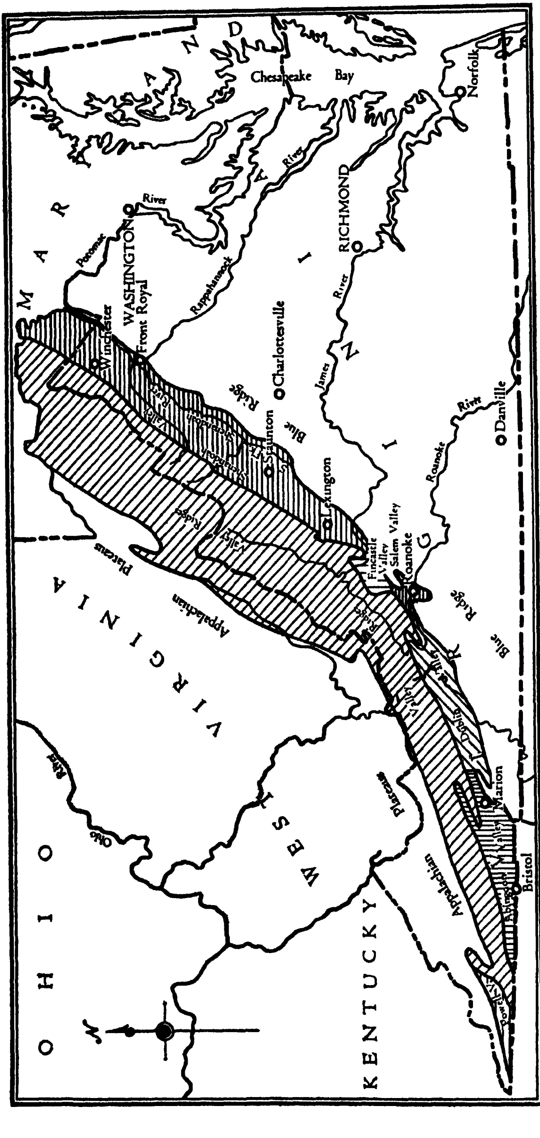


Figure 23.—Map of Virginia showing subdivisions of the Appalachian Valley and adjacent provinces. (After Stose, G. W., Virginia Geological Survey Bulletin 23.)

Valley floor. Individual members of the Valley Ridges on the west attain elevations of 3,500 to 4,000 feet above sea-level.

The Valley of Virginia is divided into six separate valleys by ridges and knobs extending eastward from the Valley Ridges and westward from the Blue Ridge (Fig. 23). Near Buchanan, for example, Purgatory Mountain constricts the Valley to a width of only 2 miles. Tinker Mountain, north of Roanoke, likewise confines the Valley within narrow limits, as do several other outlying ridges to the southwest.

Shenandoah Valley.—The largest of the valley lowlands is Shenandoah Valley, which extends from Harper's Ferry southwestward beyond Natural Bridge. Shenandoah, "Daughter of the Stars," is the Indian name for the northern part of the Valley of Virginia. It is about 150 miles long and 10 to 20 miles wide (Fig. 23). The northern part is divided into two parallel valleys by Massanutten Mountain, a prominent isolated ridge which rises abruptly a short distance east of Harrisonburg to an altitude of 3,000 feet and extends northeastward for 50 miles to the vicinity of Strasburg (Pl. 2). Massanutten Mountain is one of the dominant features of Shenandoah Valley, and its existence is due to the hardness of the folded sandstone and quartzite (Clinch) composing it, which retarded erosion while the less resistant shales and limestones of the adjacent Valley areas were being beveled by streams. An impressive view (Pl. 47) of northern Shenandoah Valley bordered by even-crested Valley Ridges to the west is to be had from the United States Forest Service observation tower on the summit of Massanutten Mountain about 3 miles northeast of Woodstock. An imposing view across that part of the Shenandoah Valley between Massanutten Mountain and the Blue Ridge, known locally as Page Valley, is afforded from the vicinity of Luray (Pl. 1). A picturesque part of the Shenandoah National Park is seen in the background.

The greater part of Shenandoah Valley and the numerous valleys and ridges to the west are drained by Shenandoah River northeastward into the Potomac. The James and its tributaries drain the mountains which border the southwestern part.

Other Valley sections.—Similar to Shenandoah Valley except in size, and adjoining it on the south, Fincastle Valley extends from Purgatory Mountain at Buchanan to Tinker Mountain near Cloverdale. The valley floor is relatively level except where dissected by the tributaries of Roanoke River. Its elevation averages 1,500 feet above sea-level.

Roanoke, or Salem, Valley, with a floor elevation of from 1,000 feet in the central portion to 1,500 feet in the southwest part, has a length of 20 miles and a width of about 8 miles. Tinker Mountain separates it from Fincastle Valley on the north and Pedlar Hills determine its southwestern border. Roanoke and Salem are along Roanoke River which drains Salem Valley.

Extending southwesterly from the vicinity of Christiansburg to Rural Retreat, Dublin Valley is 12 to 16 miles wide and embraces parts of Montgomery and Wythe counties. It is drained chiefly by tributaries of New River, although the river flows through but a small portion of the valley. The valley floor rises from an almost uniform elevation of about 2,200 feet near Blacksburg and Dublin to more than 2,400 feet near Rural Retreat.

Abingdon Valley lies largely in Smyth and Washington counties and extends from the vicinity of Marion southwest to Tennessee. Its width ranges from 10 miles at its northern end to nearly 15 miles along the State line. The valley floor varies from 2,100 to 2,300 feet above sea-level and is drained southwestward by the three forks of Holston River. Abingdon Valley, like Shenandoah Valley, is divided lengthwise by Walker Mountain.

Plate 48. Warm Springs Valley and adjacent ridges in Bath County. The Valley floor truncates a belt of Ordovician limestones along the axis of a long narrow anticline. The even crests of the sandstone ridges are remnants of former extensive peneplain surfaces. (Photograph by H. A. Strohmeyer, Jr.)

Lying between Cumberland and Stone mountains, front ridges of the Appalachian Plateau on the northwest, and Wallen Ridge, one of the Valley ridges on the southeast, is Powell Valley. Though somewhat isolated, it is a part of the Great Valley which extends southwestward into Tennessee. It is about 6 miles wide along the State line and in Lee County but narrows northward until near Big Stone Gap it is abruptly boxed off by steep ridges. The valley floor slopes to the southeast from 1,800 to about 1,500 feet. It is drained by Powell River into the Clinch, a tributary to the Tennessee.

The valleys of the Great Valley lowland have been produced by the erosion of the weaker Paleozoic shales and limestones which occur in northeasterly trending belts (Fig. 1 and Table 3). In sharp contrast is the high west slope of the Blue Ridge, consisting mainly of resistant Cambrian sandstone and quartzite with some narrow belts of shale. The prominent Valley Ridges to the west are composed chiefly of highly resistant Silurian and Devonian sandstone and quartzite.[54]

Sinks and Sink-holes.—Sinks and sink-holes, occurring abundantly in limestone areas, are conspicuous features of the Valley floor. One finds them in almost any part of the lowlands above the surface streams, and several of considerable size are to be seen along the main highways. Sinks are saucer-like or funnel-shaped surface depressions through which surface drainage descends to underground channels. They result from the enlargement of joints near the surface and the solution of the underlying limestone. Sinks are also formed through the collapse of a portion of the roof of a cave near the surface. When so formed they are generally irregular in outline and are connected with subterranean channels by nearly vertical pipelike holes. Such sinks are generally called sink-holes. They vary in size from shallow catchment basins several feet in

diameter to oval pits 200 feet or more wide and as much as 100 feet deep.

Sinks and sink-holes are closely associated with underground drainage channels. They are therefore rather accurate indicators of cavernous areas. Small ponds and lakes sometimes result from the stoppage of the outlets of sink-holes.

Valley Ridges

The Valley Ridges which occupy most of the northwestern half of the Appalachian Valley in Virginia comprise a series of roughly parallel, narrow mountain ridges and narrow intermontane valleys. The width of this belt increases from about 25 miles at New River in Pulaski County to about 45 miles in Frederick County. In the northern part of the belt three distinct chains of rather prominent ridges occur. The Virginia-West Virginia State line follows an irregular course along the crests of several of the more prominent ridges which form natural divides or watersheds. In the Valley Ridges section are numerous picturesque valleys similar to Shenandoah Valley but smaller. Some have been eroded from limestone but many are on shale. One of these is Warm Springs Valley (Pl. 48) excavated in Ordovician limestone along the axis of an anticline and in which are the famous thermal springs at Hot Springs and Warm Springs, Virginia.[54]

The most prominent of the ridges are Shenandoah, North, Little North and Great North mountains in the northern part of the region, Allegheny and Sweet Springs mountains in the central-western portion, and Peters, Walker, Clinch and Copper Ridge mountains in southwestern Virginia. The elevations of the various members of the Valley Ridges range from around 3,000 feet on Great North Mountain in Shenandoah County to more than 4,000 feet on the crest of Clinch Mountain in Russell and Smyth counties. Several knobs and peaks throughout the

Valley Ridges section attain elevations of from 4,200 to 4,500 feet above sea-level. One of these is Elliott Knob on Great North Mountain west of Staunton in Augusta County which has an elevation of 4,473 feet. In places the ridges are deeply cut by picturesque water gaps as at Buffalo Gap, Goshen Pass and the Narrows of New River.

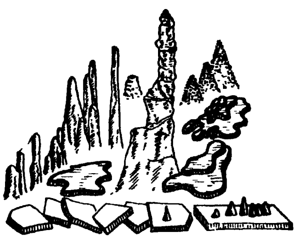
The present topography of the Valley Ridges section, its numerous interesting natural features and the beautiful scenery of this part of the State are due to the closely folded alternating resistant sandstones and weaker limestones and shales which were worn down to a peneplain that was later uplifted and dissected into the present series of ridges and valleys. The narrow, more or less even-crested, ridges are on the sandstone belts. The valleys are on belts of folded limestone or of shale.[55]

After streams and ground water had eroded the region to a gently rolling surface, or peneplain, the entire province, including the Valley of Virginia and the Valley Ridges, was uplifted more or less vertically. The erosional agents removed the weaker rocks much more rapidly than the highly resistant sandstones, thus carving out the picturesque series of valleys and ridges. Entrenchment of rivers which were flowing on the peneplain across truncated belts of sandstone has produced the many water gaps, or natural thoroughfares, through the high ridges.[56]

Appalachian Plateau

The eastern escarpment of the Appalachian Plateaus (Fig. 23) crosses a small portion of southwestern Virginia, chiefly in the western parts of Tazewell, Russell, Scott and Wise counties. This section, locally known as the Cumberland Front, is termed the Allegheny Front farther north. Sandy Ridge, Powell, Stone and Cumberland mountains are the main remnants of the escarpment in Virginia. The plateau here is a dissected upland underlain by gently folded to nearly horizontal sedimen-

tary rocks, chiefly sandstone, shale and coal of upper Paleozoic age. This part of the State, because of its average elevation of about 3,000 feet above sea-level and its humid climate, has been dissected by a maze of streams into a mosaic of steep ridges and deep valleys. It contains numerous sections and areas of much geologic interest and offers a variety of amazing scenic views. Because of the absence of limestone few caves are known and it is not probable that many will be found in this region.



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The identification of the geologic horizons in which the caverns occur was made by Dr. Charles Butts, of the United States Geological Survey, who supplied also much of the data given in Tables 1 and 3 and prepared the geologic sketch maps of each cavern area. These maps are based on a recent cooperative geologic survey of the Appalachian Valley in Virginia, by the United States Geological Survey and the Virginia Geological Survey.

The analyses of limestones in which the developed caverns occur were made by Dr. J. H. Yoe, assisted by Mr. M. C. Goldberg and Mr. Leopold Sender, all of the University of Virginia.

For photographs furnished and permission to reproduce them in this book, the writer is indebted to Dixie Caverns, for Plate 5; Endless Caverns, for Plates 7, 8, 9, 34B, 35, 39B, 41B, 45 and 46; Grand Caverns, for Plates 12, 13, 14, 15, 16, 32, 36A and 44B; Luray Caverns,

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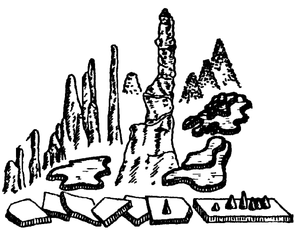

Glossary

Technical terms are here defined briefly in the sense in which they are used in this report. For more extended discussion, the reader is referred to standard text-books on geology.

Acidulated water. Water containing carbon dioxide or other mineral and organic acids.

Anticline. An arch or upfold in rocks.

Appalachian Valley. The geologic province between the Blue Ridge on the east and the Appalachian Plateaus on the west. It includes the Valley of Virginia on the east and the alternating mountain ridges and valleys (Allegheny Mountains) on the west. Also called Valley and Ridge province.

Aragonite. A mineral composed of calcium carbonate ($CaCO_3$). Colorless to white or tinted; often occurs as radiating, fibrous, needle-like crystals and also in coral-like shapes.

Areal map. A geologic map showing the distribution of bedrock formations at the surface and below the mantle rock.

Arenaceous. Sandy; containing considerable sand.

Base level. The lowest level to which land can be eroded by streams and running water.

Bedding plane. The surface between two adjacent beds of sedimentary rock.

Bedrock. Solid rock. It underlies all loose surface materials. The kinds are igneous, sedimentary and metamorphic.

Calcareous. Containing considerable calcium carbonate; limy.

Calcite. A mineral composed of calcium carbonate ($CaCO_3$). It is commonly colorless to white, has perfect rhombohedral cleavage, and effervesces in acid.

Cambrian. See Paleozoic.

Canadian. See Paleozoic.

Cave earth. Deposits of insoluble, clayey, or silty material derived from limestone during channel excavation and similar surface material inwashed through sink-holes and deposited in underground channels.

Cenozoic. The latest era of geologic time. It is subdivided into the Tertiary and Quaternary periods, the latter including the present. The time of the great development of mammals and modern plants.

Chert. A very hard, dull substance resembling flint, which occurs in limestone. It is composed of silica.

Cleavage. The property of a mineral or metamorphic rock whereby it splits readily along a smooth surface, as in slate, calcite.

Concretion. A rounded aggregate of mineral matter formed by precipitation and growth around some nucleus.

Conglomerate. A sedimentary rock composed mainly of cemented gravel.

Corrasion. Mechanical wear by streams. See erosion.

Cretaceous. The last period of the Mesozoic era.

Crystalline rock. A rock composed of minerals which have crystallized from the parent material. It commonly refers to igneous and metamorphic rocks.

Devonian. See Paleozoic.

Dip. Maximum inclination of beds of rock or fault planes to the horizontal.

Displacement. Amount of movement along a fault.

Dolomite. A limestone containing considerable magnesium carbonate ($MgCO_3$), being 45.65 per cent in true dolomite.

Drapery. Streamer-like or curtain-like forms of travertine deposits. Formed by deposition of calcium carbonate from trickling waters or through the union of a row of stalactites.

Dripstone. Deposits of travertine formed by the drip of water charged with calcium bicarbonate; stalactite, stalagmite.

Epoch. Part of a geologic period.

Era. The longest division of recorded geologic time.

Erosion cycle. The succession of events, and the time involved, during the erosion of a region from its initial form to base level.

Fault. A fracture in rock along which there has been displacement.

Fault block. A mass of rock displaced along a fault.

Ferruginous. Containing iron.

Fissile. Having the ability to split readily.

Flowstone. Travertine deposits formed by trickling or flowing waters. Occurs chiefly on cavern walls or at the junction of tributary and main channels.

Fold. An upwarp (anticline) or downwarp (syncline) in rocks, caused by pressure.

Formation. A unit of geologic mapping consisting of "rocks of uniform

character or rocks more or less uniformly varied in character." Also applied in caverns to travertine deposits.

Fossil. Remains or traces of ancient plants or animals embedded in sedimentary rocks, as shells, tracks.

Fossiliferous. Containing fossils.

Friable. Crumbly or loosely cemented.

Gallery. An underground channel or level. A portion of an abandoned channel or level above the main passage.

Geosyncline. A large downfold or sinking trough in the earth's crust.

Granite. A granular, crystalline, igneous rock composed of quartz, feldspar and other minerals.

Great Valley. See Valley of Virginia.

Ground water. Underground water which occupies cavities in rocks.

Group. An assemblage of two or more closely related formations.

Helictite. A curious branching or curved type of travertine deposit. It results most probably from impurities in the dripping water and from the effect of air currents in directing growth.

Horizon. A definite zone in a formation or in a series of rocks.

Igneous rocks. Rocks which have been formed by the cooling and hardening of molten rock materials.

Impervious rocks. Rocks that will scarcely allow water to move through them, as shale, clay.

Intermediate channel. An almost horizontal channel between two well-defined levels.

Intersecting channel. An opening between two cavern channels or levels. Varies in size and shape from pipelike holes to chasmlike rifts.

Intermontane valley. A valley between mountains; Warm Springs Valley.

Joint. A crack or fissure in rock. Joints generally occur in two sets, one of which is parallel to the strike of the formation and the other is at right angles, thus dividing the rock into large blocks.

Level. One or more channels of a cavern system excavated at about the same elevation.

Limb. One side of a fold.

Limestone. A sedimentary rock composed largely of calcium carbonate ($CaCO_3$). It is produced by the action of algae and invertebrates and by the precipitation of calcium carbonate from water.

Mantle rock. Loose, surficial material above bedrock, as gravel, sand, clay.

Marble. A calcareous metamorphic rock produced by the recrystallization of limestone.

Marine. Pertaining to the ocean. Marine sediments were deposited in oceanic waters.

Mature topography. A surface which has reached the maximum stage of dissection by streams; a very hilly region.

Meandering. Pertaining to streams that wind in broad curves, as Shenandoah River.

Mesozoic. Next to the last great era (Cenozoic) of recognized geologic time. Follows the Paleozoic era. Includes the Triassic, Jurassic and Cretaceous periods. The time of the development of the great reptiles and of the first hardwood forests.

Metamorphic rocks. Igneous or sedimentary rocks greatly altered by heat

and pressure. Slate is metamorphosed shale and marble is metamorphosed limestone.

Mississippian. See Paleozoic.

Monadnock. A hill that remains upon a peneplain, either because the rock is more resistant to erosion than the surrounding rock or because it was far from the main streams. An erosion remnant, as Massanutten Mountain.

Monocline. Beds of rock dipping in one direction.

Nodule. A small, irregular to roundish lump of a substance formed in a rock; for example, chert in limestone.

Old age. That stage in the development of a region when it has been largely eroded to a lowland plain.

Ordovician. See Paleozoic.

Outcrop. An exposure of rock at the surface.

Ozarkian. See Paleozoic.

Paleozoic. The third great era of recorded geologic time. The time of great development of invertebrates, fish and fernlike plants. The era is subdivided commonly into seven periods: Cambrian (oldest), Ordovician, Silurian, Devonian, Mississippian, Pennsylvanian and Permian. Some geologists use the terms, Ozarkian and Canadian, for the later Cambrian and the earlier Ordovician, respectively. The time terms are also used to designate the rocks formed during the same periods, as the Cambrian system of rocks formed during the Cambrian period.

Passage. An underground channel, or level, in a cavern.

Peneplain. An almost flat plain of great extent which has been formed

at, or near, base level by erosion by running water. The almost finished product of an erosion cycle.

Pennsylvanian. See Paleozoic.

Period. The second largest division of geologic time. Corresponds to a system of rocks.

Permeable. Having a texture that permits the movement of ground water.

Physiography. The description and interpretation of the surface features of the earth.

Pre-Cambrian. (1) All recorded geologic time before the beginning of the Paleozoic era. (2) Very old crystalline rocks.

Province. A region characterized by the same, or closely similar, features; for example, the Blue Ridge province.

Quartz. A very common mineral composed of silica (SiO_2). Colorless to white; very hard (scratches glass).

Quartzite. A metamorphosed sandstone. The grains of quartz sand have been firmly cemented by silica which has recrystallized around them.

Quartzose. Containing considerable quartz.

Quaternary. Second period of the Cenozoic era, consisting of Pleistocene and Recent time. Often called the "glacial period."

Recent. Geologic time since the glacial epoch, including the present.

Rejuvenation. Pertaining to streams which have had their gradients, and therefore their velocities and erosive powers, increased.

Relief. Difference in elevation in an area. Irregularities of the surface.

Resistant rocks. Rocks which disintegrate slowly under the attacks of ero-

sive agents, such as streams. Chiefly sandstone, quartzite and certain crystalline rocks.

Rift. A relatively long and narrow opening above or between underground channels. See Intersecting Channel.

Rills. Tiny channels made in ceilings, walls and floors of cavern channels by circulating water.

Sandstone. A sedimentary rock composed of cemented grains of sand, commonly particles of quartz.

Schist. A foliated crystalline metamorphic rock which has cleavage.

Secondary. Material derived from solution of other rocks and redeposited, such as calcite or travertine, by streams and ground water.

Sedimentary rocks. Rocks in beds composed of particles of other rocks, organic remains, or materials deposited from solution in water; such as sandstone, limestone and shale. Most fossils are found in them.

Series. Two or more formations which make up a major division of a system of sedimentary rocks.

Shale. A sedimentary rock composed of particles of clay and mud pressed and cemented together.

Sheet. A type of travertine deposit resembling a sheet, occurring usually as a relatively thin coating. Formed on walls, shelves, benches and terraces by trickling or flowing water. Occurs also along bedding planes.

Shield. A disc-shaped travertine deposit on cavern walls and ceilings. Varies in size but is commonly about the thickness of sheet deposits, to which it may be related in origin.

Siliceous. Containing silica (SiO_2).

Silt. Insoluble fine sediment. See cave earth.

Silurian. See Paleozoic.

Sink. A surface depression formed by solution along a joint in the underlying limestone, or similar rock.

Sink-hole. A sink connected with an underground channel or cavern by a visible opening. Formed by enlargement of a sink or by collapse of the roof of a cavern near the surface.

Stalactite. An icicle-like travertine deposit on cavern ceilings or under ledges formed by the drip of water containing calcium bicarbonate.

Stalagmite. A blunt, inverted, cone-shaped or columnar travertine deposit on the floor of a cavern or on broken limestone blocks and benches.

Stratified. In beds or layers; for example, sedimentary rock.

Stratigraphy. The description and interpretation of the succession and relations of rocks.

Stratum. A bed or layer of rock. (Pl. strata.)

Strike. Horizontal direction on a bed of rock; the trend of a fold.

Structure. Arrangement of rocks in the earth's crust.

Structure section. A vertical section showing the rocks as they would appear in the wall of a deep cut.

Syncline. A downfold in rocks.

System. All the rocks formed during a geologic period; for example, Cambrian system.

Terrace. A benchlike flat above a stream; part of a former valley floor.

Also, deposits of transported material occurring along underground channels, and generally covered with a layer of flowstone.

Tertiary. First period of the Cenozoic era; just prior to Quaternary time.

Topography. The surface form or shape of the land.

Travertine. Calcium carbonate ($CaCO_3$) deposited from solution in underground and surface waters. Embraces the various types of cave deposits such as stalactite, stalagmite, dripstone and flowstone.

Vadose water. Ground water above the water table.

Valley of Virginia. The broad, elongate lowland, or series of valley-like lowlands, just west of the Blue Ridge. The eastern part of the Appalachian Valley in Virginia. Includes Shenandoah Valley.

Valley Ridges. The mountain ridges and intervening valleys west of the Valley of Virginia.

Vein. A deposit of mineral matter in a joint or crevice.

Vent. See Intersecting channel.

Water gap. A narrow, deep passage cut by a stream through a ridge; Goshen Pass, Panther Gap, Narrows of New River.

Water table. The upper surface of the zone saturated with ground water.

Weak rocks. Rocks which offer slight resistance to erosion, as shale.

Weathering. The slow action of geologic agents at or near the surface whereby rocks decay and disintegrate.

Wind gap. Generally an abandoned water gap; as Swift Run Gap.

Youth. An early stage in the erosion cycle characterized by partial dissection of the land. "Most of the erosion of the land remains to be done."

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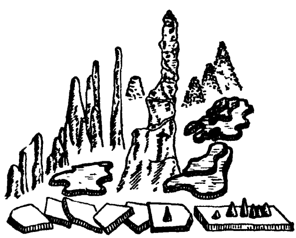

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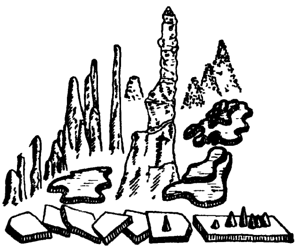

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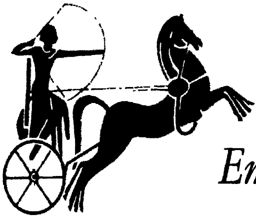

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